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Application of High-Lift Devices to Airplanes Designed Primarily for High Cruising Speeds

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ABSTRACT

A method is presented for easily determining the effects of high-lift devices upon the free-flight performance characteristics of airplanes in both normal and reduced-power operation. For improvement of these characteristics, a high lift-drag ratio is shown to be more important than a high lift coefficient. Relative performance characteristics are computed for airplanes equipped with plain wings, with split flaps, and with two recently tested N.A.C.A. high-lift devices. The analysis indicates that these devices may be beneficial to airplanes designed primarily for high cruising speeds or high efficiency at cruising speed, even though all considerations of landing and take-off are omitted.

INTRODUCTION

IN a previous institute paper[1] Ben O. Howard said, "The question of high wing loading is one much discussed among pilots. Naturally the only concern of the pilot in this matter is airplane behavior, and all pilots appreciate the advantages of a heavily loaded wing at high speed." These advantages result from the fact that the acceleration due to a vertical gust varies directly as the flight speed and inversely as the wing loading, approximately. From this relationship, it is evident that high wing loadings are not only advantageous to the pilot but greatly increase passenger comfort and decrease the critical gust loads for which the structure must be designed. Inasmuch as these effects vary directly as the flight speed, they are becoming more important as cruising speeds increase.

Further advantages of a high wing loading result from the reduction in wing surface. These advantages are an increase in airplane efficiency at the cruising speed and a decrease in the weight, the construction cost, and the maintenance cost of the wing covering. The potential saving in weight and cost of wing covering has been increased since the realization of the drag reductions that may be obtained through improvement of the accuracy of wing contours and surface finish, because such improvement will cause an increase in cost and weight per unit area of the wing surface.

The advantages of high wing loadings, though becoming of greater importance, have been known for many years. Airplane designers have been quick to seize upon high-lift devices that would allow them to increase wing loadings and yet meet definite landing and take-off requirements. Thus the design of airplanes, including the choice of high-lift devices, has been made primarily for compliance with these landing and take-off requirements, usually at the expense of performance in free flight.

Designers have long felt that the free-flight performance of airplanes could be greatly improved if it were not necessary to consider landing and take-off requirements. Improvement of landing fields and the use of the tricycle landing gear have made and will continue to make these requirements less stringent. Other methods of meeting the problem include various schemes for assisting take-off, fueling after take-off, and reducing the fuel or cargo load before landing. Airplanes designed to cruise at high altitude, moreover, have less difficulty meeting landing and take-off requirements. Because of the foregoing considerations, it will be possible to design many types of airplanes primarily for high cruising speeds or high efficiency at cruising speed, taking full advantage of high wing loadings and without regard to the landing or take-off characteristics. The scope of the present paper is to discuss the application of high-lift devices to such airplanes.

HIGH-PERFORMANCE AIRPLANES

Before the application of high-lift devices to high-performance airplanes is discussed, it will be desirable

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to discuss briefly some of the characteristics of such airplanes. The primary consideration will be low drag or high ratio of lift to drag at cruising. Not only should the airplane cruise near its maximum lift-drag ratio, but that ratio should be made large by proper choice of wing section, span, and loading, as well as by the elimination of all unnecessary parasite drag. The wing area should be made small to reduce profile drag and the span should be made large to reduce induced drag. In general, the wing section should be so chosen as to give a maximum profile lift-drag ratio at the cruising lift coefficient.

Effects of High-Lift Devices

Since it was assumed that landing and take-off characteristics will be ignored, the cost, the weight, and the complication of high-lift devices must be balanced against improvement in the rate of climb and the ceiling with normal power and with reduced power, as in the event of partial engine failure. The effect upon speed range with any given amount of power and upon minimum sinking speed without power may also be of some importance.

A simple method of predicting the effects of high-lift devices upon the free-flight characteristics of airplanes has been devised. In order to illustrate the method and to determine the relative merits of the conventional split flap and of the most recently developed N.A.C.A. high-lift devices, the characteristics of airplanes with plain wings, with split flaps, with slotted flaps, and with venetian-blind flaps will be calculated. In this analysis only the effects of the high-lift devices on wing lift and drag are considered. A more thorough analysis, including secondary effects, should be made in the application of devices to particular airplanes. The same method of analysis may, nevertheless, be found useful.

In the analysis the following symbols are employed:

C = ratio of thrust power available to cruising thrust power.
C_D = airplane drag coefficient.
C_{D_0} = wing profile-drag coefficient.
C_{D_i} = induced-drag coefficient.
C_{D_P} = parasite-drag coefficient.
C_L = airplane lift coefficient.
D = airplane drag.
d_0 = wing section profile drag.
K = ratio of thrust power required for level flight to cruising thrust power.
L = airplane lift.
l = wing section lift.
N = total number of engines.
P = thrust power.
q = dynamic pressure.
R = ratio of cruising engine power to rated engine power.
S = wing area.
V = flight speed.
V_c = rate of climb.
V_s = sinking speed.
W = airplane weight.
ρ = mass density of air.
$( )_1$ refers to cruising conditions.

Wing Section Characteristics

The basic airfoil and high-lift devices, which are shown in Fig. 1, have been tested in the N.A.C.A. 7 by 10 foot closed-throat wind tunnel[2,3] under practically identical conditions. The section envelope polars are given in Fig. 2.

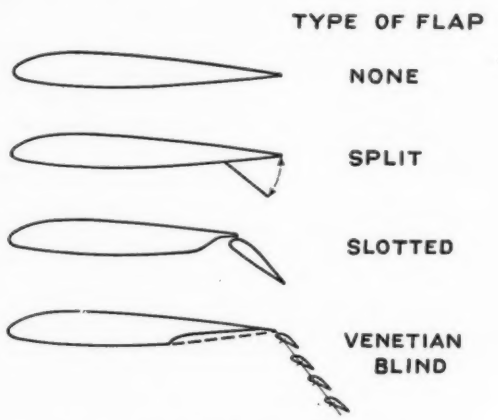

Fig. 1. Plain airfoil and high-lift devices.

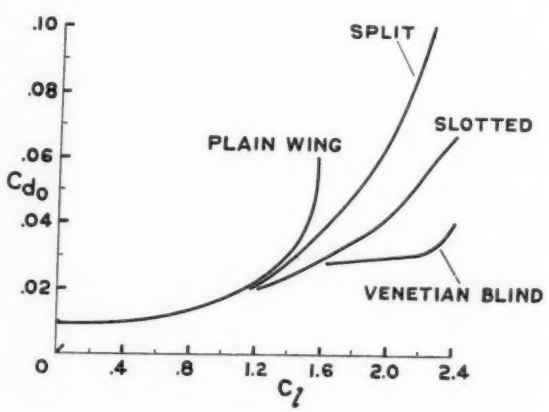

Fig. 2. Profile-drag envelope polars.

Airplane Polars

As previously stated, a high-performance airplane should have a high aspect ratio, should cruise at a high lift coefficient, and should employ a wing section giving maximum l/d_0 at the cruising lift coefficient of the airplane. These conditions are reasonably well satisfied by an airplane employing the N.A.C.A. 23012 section, having an aspect ratio of 24, having a parasite-drag coefficient of 0.01, and cruising at a lift coefficient

of 0.85. Polars for such an airplane are shown in Fig. 3; the cruising L/D is seen to be 25.4. An elliptic span-load distribution and a constant parasite-drag coefficient have been assumed.

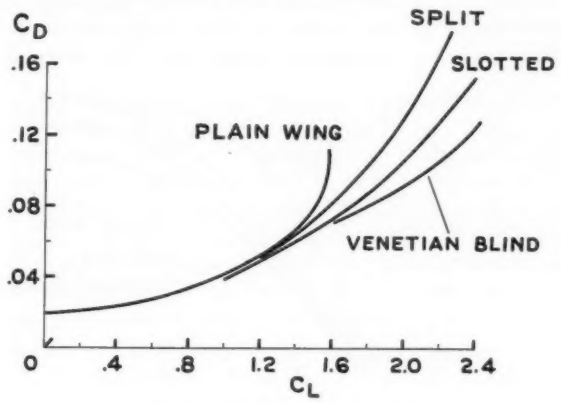

FIG. 3. Airplane envelope polars.

It may be noted at the outset that these polar curves, as well as all subsequent data, apply to an entire family of geometrically similar airplanes and to all possible wing and power loadings, neglecting the effects of scale. For steady horizontal flight at any particular lift coefficient, however, the following relationships exist:

$$\text{Wing loading} = W/S = qC_L \tag{1}$$

$$\text{Thrust-power loading} = W/P = (1/V)(L/D) \tag{2}$$

With these equations, the data may be applied to airplanes of a particular size, weight, and power.

Power Required in Level Flight

For convenience, the thrust power required for steady horizontal flight at any lift coefficient and at any altitude will be determined as a multiple K of the thrust power required for level flight at a particular lift coefficient and altitude. Any particular conditions may be assumed but, in the following analysis, the ratios will be based upon the normal cruising conditions. It may be shown that

$$K = \left(\frac{\rho_1}{\rho}\right)^{1/2} \frac{C_{L_1}^{3/2}}{C_{D_1}} \frac{C_D}{C_L^{3/2}} \tag{3}$$

or

$$\left(\frac{\rho}{\rho_1}\right)^{1/2} K = \frac{C_{L_1}^{3/2}}{C_{D_1}} \frac{C_D}{C_L^{3/2}} \tag{4}$$

Eq. (4) will generally be found the more convenient because the right-hand member is independent of altitude.

In Fig. 4 are plotted curves of $(\rho/\rho_1)^{1/2}K$ against lift coefficient obtained by substitution of the data of Fig. 3 in Eq. (4). The power-required factors are based on conditions at the optimum cruising lift coefficient ($C_L = 0.85$). The high-lift devices not only increase the speed range on a given amount of thrust power but decrease the minimum thrust power required for level flight. This decrease of minimum thrust power is of great importance in the event of partial engine failure, as will be discussed later.

The equations show that the power required for level flight is directly proportional to $C_D/C_L^{3/2}$ and that the minimum power required will occur at the same lift coefficient for a given airplane polar, regardless of altitude or cruising conditions. Any high-lift device that reduces the $C_D/C_L^{3/2}$ of the airplane will be likely to improve its rate of climb and ceiling and its ability to fly at reduced power. In the choice of devices for such improvement it will therefore be evident that a high ratio of lift to drag is more important than a high lift coefficient. It would be expected, moreover, that the conventional split flap, though of some benefit, would be much inferior to the more recently developed devices, as indicated by the curves of Fig. 4.

Rate of Climb

The rate of climb is assumed proportional to the difference between the thrust power available and the thrust power required for level flight at any given lift coefficient. That is,

$$V_c = (C - K)P_1/W \tag{5}$$

where P_1 is cruising thrust power and C is the ratio of thrust power available to thrust power at cruising. For any given values of P_1/W and C, the maximum rate of climb will occur at the minimum value of K. The possible improvements in rate of climb that can be obtained through the use of the high-lift devices are evident from the curves of Fig. 4.

Ceiling

The absolute ceiling on a given amount of power is that altitude at which the thrust power available is equal to the minimum thrust power required for level flight; that is, when $C = K_{min.}$. In general, therefore, the lower the value of $K_{min.}$, the higher will be the

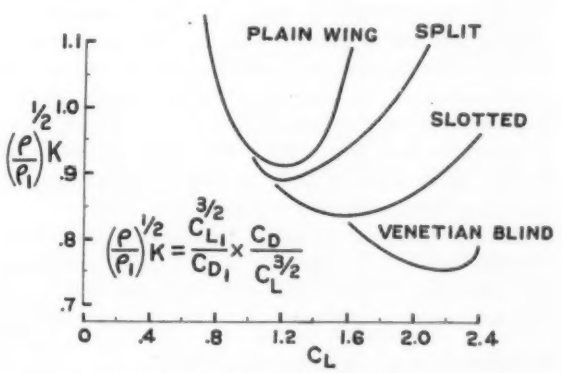

FIG. 4. Level-flight power-required factors.

ceiling. Improvement due to the use of high-lift devices is indicated by the curves of Fig. 4.

Engine Failure

In the event of complete engine failure, high-lift devices would, in general, be expected not to increase the gliding range. They may, however, decrease the minimum sinking speed ($V_{s_{min.}} = K_{min.} P_1/W$), and they will certainly decrease the landing speed.

Perhaps more important than complete engine failure is the condition of partial engine failure, that is, the failure of one or more engines on a multi-engine airplane. The minimum power required from the remaining engines for level flight at any altitude may be computed if the airplane and the propeller characteristics are known. In Fig. 5 are plotted curves of required engine output in terms of rated output for bimotor and trimotor airplanes after failure of one engine, assuming constant propulsive efficiency, as computed from the $(\rho/\rho_1)^{1/2}K_{min.}$ values of Fig. 4.

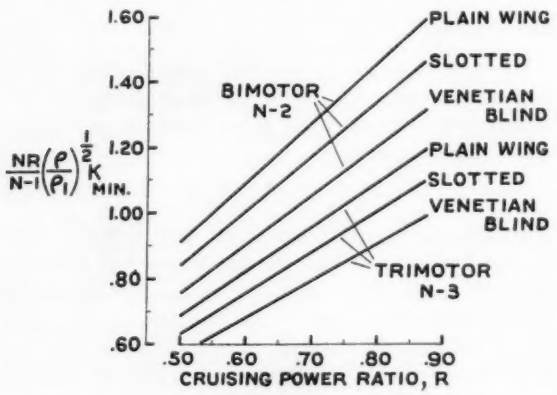

FIG. 5. Minimum engine-output factors for level flight with one engine dead.

These curves apply to airplanes with more than three engines after failure of one-half or of one-third of the engines, respectively. Curves for the split flap are omitted, because it has been shown to be of little benefit. The requirement for flight at other than the cruising altitude may be determined by application of the density correction, $(\rho_1/\rho)^{1/2}$. For example, if cruising altitude is 8000 ft., $(\rho_1/\rho)^{1/2}$ for sea level is 0.886. Thus a bimotor airplane which cruises on 0.75 rated power at 8000 ft. could fly on one engine at sea level at rated power ($0.886 \times 1.13 = 1.00$) with a venetian-blind flap. With the flap retracted, it would require $0.886 \times 1.37 = 1.21$ rated power, that is, a 21 percent engine overload.

The curves of Figs. 4 and 5 indicate that the use of suitable high-lift devices may improve the level-flight and climbing performance, including the ceiling, of high-performance airplanes after partial engine failure.

Reduction of $K_{min.}$ by Reduction of C_{L_1}

Thus far this paper has discussed the reduction of $K_{min.}$ by the use of high-lift devices. An alternative or supplementary method is by reduction of the cruising lift coefficient, C_{L_1}, with accompanying reduction of wing loading. The minimum power-required factors and the cruising L/D for the airplanes represented by the polars of Fig. 3 are plotted in Fig. 6 against cruising lift coefficient. The decrease

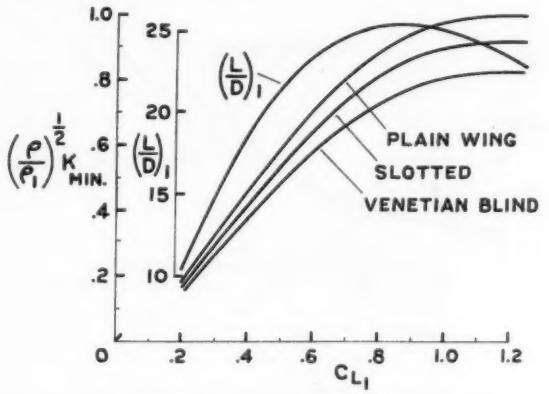

FIG. 6. Effect of cruising lift coefficient upon minimum power-required factors and cruising lift-drag ratio.

in cruising L/D at values of C_{L_1} below its optimum value can readily be seen. Other injurious results of a decrease in the cruising lift coefficient are an increase in the design load factors and in the wing surface required, as well as a detrimental effect upon the behavior of the airplane as affecting both pilot and passengers. In short, a reduction of cruising lift coefficient entails some loss in each of the advantages of a high wing loading. In an analysis of the application of high-lift devices, these losses should be compared with the cost, the weight, and the complication of the high-lift devices.

CONCLUDING REMARKS

It has been shown that some types of high-lift devices may be beneficial to airplanes primarily designed for high cruising speeds or high efficiency at cruising speed even though all considerations of landing and take-off are omitted. The accompanying beneficial effects upon the landing and the take-off characteristics, even if not essential, may often be of additional value.

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Some Stress-Strain Studies of Metals

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STRESS-STRAIN curves and the related mechanical properties have long been used as a means of judging the quality and usefulness of metals and to provide basic engineering data for use in the design of metal structures and parts. The relations between stress, deformation and time also provide necessary data for the manufacture and fabrication of structural or machine parts. In some instances where creep and elastic recovery of plastic deformation occur, it may be essential to consider time in structural behavior.

It is the purpose of this paper to review the significance of certain mechanical properties as indicated by stress-strain curves and their relation to the previous history of stress and deformation, particularly the effects of cold working and cyclic stressing upon the mechanical properties and the shape of the stress-strain curve. The mechanical properties of a metal may be defined in terms of the characteristics of the complete stress-strain curve which from this point of view is a graphical representation of the mechanical properties and the inter-relations between them. Conversely the mechanical properties substantially define, in numerical terms, the general shape of the complete stress-strain curve. This is illustrated in Fig. 1 which shows typical complete tensile stress-strain curves for various commercial metals, all plotted to the same scale. In Fig. 2 portions of the same stress-strain curves have been replotted with the strain scales very much magnified in order to emphasize the differences in moduli of elasticity, proportional limits, yield points, and yield strengths. The characteristic flat spot or yield point in the stress-strain curve of the steels and the absence of any such pronounced flat spot in most of the other metals is clearly indicated in Figs. 1 and 2. The yield strengths of those metals having no definite yield points are indicated in Fig. 2

The significance of the more common mechanical properties in terms of the relationship between the shape of the stress-strain curve for engineering design and metal structures or machine parts, is reviewed for the purpose of establishing a common point of view for this paper.

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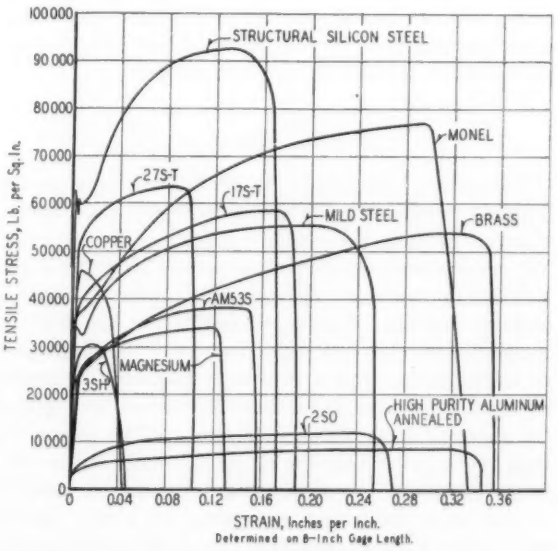

FIG. 1. Typical complete stress-strain curves for several metals. 27S-T and 17S-T are heat treated aluminum alloys. 3S-H is a cold worked aluminum alloy. AM53S is a magnesium alloy. 2S-O is annealed commercially pure aluminum. High purity aluminum is at least 99.95 percent aluminum.

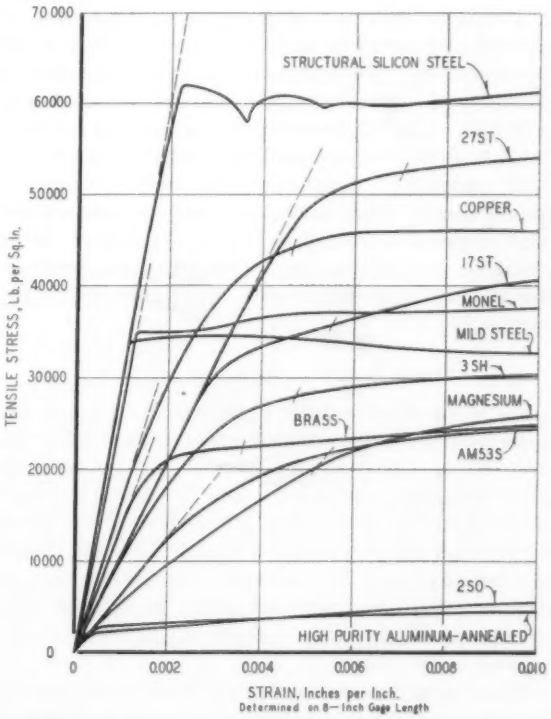

FIG. 2. Typical stress-strain curves for metals shown in Fig. 1 (strain scale expanded).

Modulus of Elasticity

Defined in terms of the stress-strain curves the modulus of elasticity is the numerical value of the slope of the initial straight-line portion of the tension or compression stress-strain curve and is expressed in lb. per sq.in. For members of identical dimensions, the deflections under a given load within the elastic range are inversely proportional to the modulus of elasticity. Furthermore, members of identical dimensions, which tend to buckle under compressive loads within the elastic range, display critical loads directly proportional to the modulus of elasticity. From these two standpoints a high modulus of elasticity is advantageous. A high modulus, however, may offer certain disadvantages. For example, in members of identical cross section the stresses resulting from shock loads within the elastic range are directly proportional to the modulus of elasticity. Another example is found in the case of members of identical dimensions which are subjected to fixed deformations imposed upon them by deformations or misalignments of adjacent parts. In such cases the stresses are directly proportional to the modulus of elasticity of the material.

Proportional Limit

The proportional limit of a material indicates the upper limit of stress for which the stress-strain curve of the material is a straight line. This represents the maximum stress for which the theory of elasticity applies rigidly. It is a very poorly defined property of material and one which cannot be precisely determined experimentally. Furthermore, it is a property which is extremely sensitive to small amounts of cold work and overstress. The engineering importance of proportional limit is often over-emphasized by those who assume mistakenly, that theoretical analyses based on assumptions of elastic action are totally invalidated by small departures from perfect proportionality. Most allowable working stresses for structural materials do not produce any measurable departures from proportionality.

Yield Strength and Yield Point

For steels which exhibit a definite yield point, the upper yield point is the highest stress reached before the stress-strain curve breaks over. This upper yield point represents, therefore, a very definite upper limit of useful stress. Since there is very little departure of the stress-strain curve from a straight line, the theory of elasticity may be considered applicable for all stresses below this yield strength. From such considerations a high yield strength is definitely advantageous.

When some materials are tested in the usual manner, the stress-strain curve exhibits a dip at strains slightly greater than that producing first permanent set. The mean value of stress in the bottom of this dip is often referred to as the lower yield strength. This lower yield point of mild steel may be construed to represent the lower limit of stress at which yielding will continue after it is once started. Materials exhibiting a lower or secondary yield point usually exhibit pronounced patterns of "Luders" lines when plastically deformed.

Yield strength, based on an accepted arbitrary amount of permanent set, was devised in an effort to provide, for metals which had no well-defined point of yielding in their stress-strain curves, a clearly defined stress which would serve the same general engineering purposes as the yield point. Experience has shown that yield strength, based on the commonly accepted amounts of permanent set, serves this purpose satisfactorily. Yield strength has generally been accepted by engineers and designers on about the same basis as the yield point in steel. In using the term, however, engineers should never lose sight of the essential differences between yield strength and yield point, and these differences are best understood by remembering the shapes of the corresponding stress-strain curve. The practical importance of these differences is well illustrated by the case of forming or straightening a piece of metal. Steels with a well-defined yield point can usually be given a considerable degree of permanent set in forming operations without exceeding the upper yield point of the material. Materials without well-defined yield points, however, usually require stresses appreciably in excess of the yield strength in order to accomplish any considerable amount of forming. Another difference is found in the case of the collapse of members under compressive forces. For metals with a definite yield point, collapse almost invariably accompanies the application of a stress equal to the yield point, whereas in the other type of material it is frequently possible to exceed the yield strength appreciably without producing complete collapse.

Tensile Strength

The stress corresponding to the highest point on the ordinary tensile stress-strain curve is generally understood as defining the tensile strength of the material. The engineering significance of tensile strength is too well understood to require elaborate comment, but it is perhaps not out of place to recall that the load at tensile failure on a structural member or machine part in service is not always accurately predicted by multiplying its minimum net area by the tensile strength of the material from which it is made. The reason for this, of course, is that the stress is usually not so uniformly distributed over the net area in a service member as it is in a tensile test specimen. In a very ductile metal this nonuniformity of stress is often largely eliminated by plastic yielding so that the breaking strength approximates the predicted strength even on a cross-section containing rivet holes and other discontinuities. In the case of less ductile materials, how-

ever, the breaking strength may prove to be considerably less than the predicted strength.

Elongation

The total amount of permanent strain in the gage length of a tensile specimen is known as elongation. Elongation is widely used as a rough measure of the ductility of a metal under the action of tensile forces, but the engineering significance of the numerical value of elongation is today a moot question.

It is well known that the elongation of a tensile specimen is a function of the size and shape of the test specimen. Evidence of this variation is found in most mechanical property specifications which show different minimum elongations for various thicknesses of material. Furthermore, the value of elongation in a tensile specimen is a function of the gage length used. This is well illustrated in Fig. 3 which shows the variations in elongation which result from using different gage lengths on $^1/_2$ inch diameter tensile specimens. It will

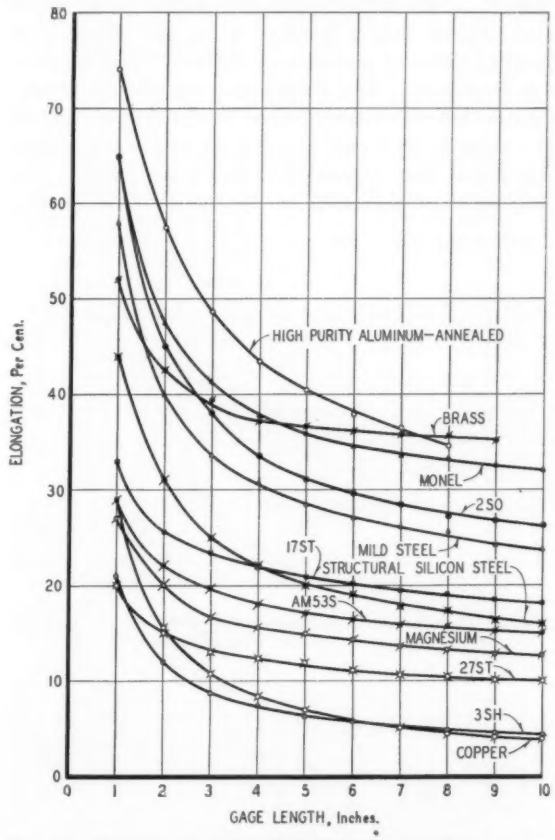

Fig. 3. Variation of elongation with gage length for metals shown in Fig. 1.

be noted that in several instances the curves for the various materials cross each other so that one metal may have a higher elongation than another for one gage length and a lower elongation for some other gage length. The particular requirements that a material must meet in service depend primarily upon the design of the machine or structural part and the use to which it is put. These facts indicate some of the difficulties of attempting to assign a definite engineering significance to the numerical value of elongation for a material.

Since the shape of the stress-strain curves of metals and the related mechanical properties are considerably affected by cold working, and since heat treated wrought metals are often subjected to various cold working operations in the plant of the manufacturer or in the construction shop of the user, it is important that the engineer should familiarize himself with some of the effects of cold working.

For consideration in this paper cold work has been classified as unidirectional and polydirectional. Unidirectional cold work is obtained by deforming the metal by stressing it in only one direction, such as occurs in stretch-straightening. Polydirectional cold work is obtained by deforming the metal by stressing it in two or three principal directions. For this type of cold work the stresses may be all of the same kind, as occurs in upsetting with lateral restraint, or be of opposite kind, as occurs in drawing material through a die. In the latter case the drawing force produces tension in the direction of drawing and the die pressure imposes compressive stresses normal to that direction.

In order to investigate the effects of unidirectional cold work produced by stretching, tests were conducted on a lot of $^3/_4$ inch rod in alloy 52S* cold worked by drawing through dies to the temper known as "three quarter hard" ($^3/_4$H). This lot of rod was divided into three parts: one part was retained in its original cold worked condition; the other two were annealed. Of the two annealed portions, one was retained in the annealed condition and the other was stretched 20 percent. From each of these three portions of rod, two specimens, one tensile and one compressive were machined and tested. The results are shown in Fig. 4 with the tensile stresses plotted positive and compressive stresses negative. A study of this figure reveals that

* Navy Specification 46A11.

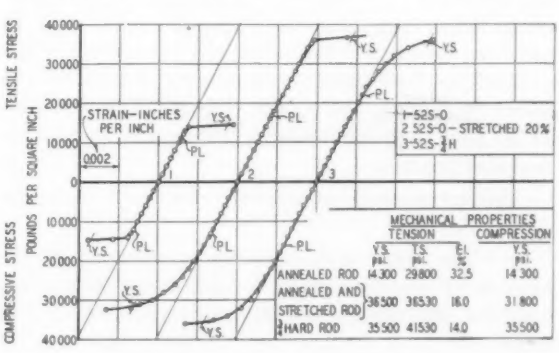

Fig. 4. Tensile and compressive stress-strain curves of 52S rod showing the effects of unidirectional cold work and a polydirectional cold work.

the stress-strain curve in tension is of substantially the same shape as the stress-strain curve in compression for the annealed condition, which represents zero cold work. The same is true for the $^3/_4$H condition, which represents a condition resulting from polydirectional cold work. The material stretched 20 percent, however, displays a marked difference in shape of stress-strain curve between the tensile and compressive portions. The tension half of the stress-strain curve has a rather sharp "knee" at a stress slightly below the yield strength, whereas the compression half is much more gradually rounded. This is characteristic of material which has been stretched.

Comparing Curves 2 and 3 in Fig. 4, it will be found that the tension halves of the curves show approximately the same yield strength but decidedly different shapes, whereas the compression halves of the two curves show approximately the same shape with the $^3/_4$H material having the higher yield strength. This demonstrates that different types of cold working can be applied to produce identical yield strengths in tension without producing the same general stress-strain relation.

In addition to the stress-strain curves, Fig. 4 also shows a summary of the mechanical properties of the 52S material in the three different conditions. This tabulation shows that the ultimate strength in tension for the stretched material is almost identical with the yield strength in tension, indicating that the stress applied to stretch the material 20 percent was very close to the original ultimate strength of the annealed material. It is also interesting to note in this tabulation that the ultimate strength in tension for the stretched material is distinctly higher than the ultimate strength for the unstretched material. In other words, the stretching has not only raised the proportional limit[1] and yield strength* but has also increased the tensile strength of the material. At first thought this may seem impossible, but it should be remembered that in testing the stretched material the tensile specimen is cut from the rod after it has been stretched so that any reduction in area of the original rod which accompanied the stretching is obliterated. If, instead of machining the specimen from the stretched rod the tensile strength had been determined by testing the full section of the rod and had been based on the original area of the rod before stretching, the tensile strength thus obtained would have been substantially the same as that of the annealed material.

Other interesting comparisons to be drawn from Fig. 4 are as follows:

(a) The modulus of elasticity is substantially the same in all three curves indicating that cold working does not appreciably influence this property of this metal.

* 0.2 percent set.

(b) The yield strengths are distinctly greater for the cold worked material than for the annealed material, and the same is true to a lesser degree of the proportional limits except that the stretching operation produced almost no change in the compressive proportional limit.

(c) For the stretched material, the increase in strength compared to the annealed material is greater for the tension half of the curve than for the compression half.

Tensile and compressive stress-strain curves from two other investigations very similar to that just described are shown in Figs. 5 and 6. The details of these investigations are as follows:

Fig. 5. This investigation was carried out on $^3/_4$ inch diameter aluminum rod* which was originally cold worked by drawing through dies to the temper known as full hard (H). The rod was divided into seven lots, six of which were annealed and then stretched different amounts varying from zero to 20 percent.

Fig. 6. This investigation was conducted on 24S-T tubes divided into a number of groups which were stretched different amounts at different intervals after heat treatment. The tensile and compressive stress-strain curves were determined on the full cross-section of the tubing in each case. The tests were made several days after heat treatment. Thirty-six tension and compression stress-strain curves are involved in this

* 99.5 percent Aluminum.

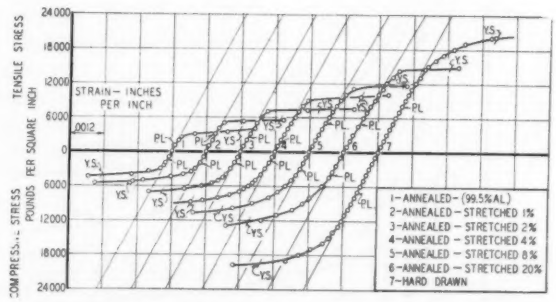

FIG. 5. Tensile and compressive stress-strain curves of aluminum (99.5 percent) rod showing effect of cold work.

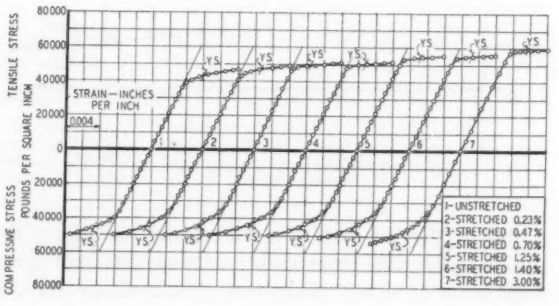

FIG. 6. Tensile and compressive stress-strain curves of 24S-T tubing showing effect of stretching.

investigation of which a selected group of seven are given in Fig. 6.

A comparison of Figs. 5 and 6 with Fig. 4 shows that the same trends discussed in connection with the 52S rod are present in the other aluminum alloys. The percent increase in the various properties for a given amount of stretching is not nearly so great in the case of the heat treated material, however, as in the case of the annealed 52S and aluminum rod.*

From the standpoint of the engineer, the effect of stretching is perhaps most important in its effect on the yield strength. With this in mind, three charts, Figs. 7, 8, and 9, have been prepared using data taken from the investigation represented by Figs. 5 and 6 and similar data not included in this paper. Fig. 7 shows that for aluminum rod* the tensile yield strength increases very rapidly with increasing amount of stretch, doubling the value for annealed material at about 2 percent stretch and tripling this value at about 7 percent stretch. The increase in compressive yield strength is definitely less rapid than that for tensile yield strength.

* 99.5 percent Aluminum.

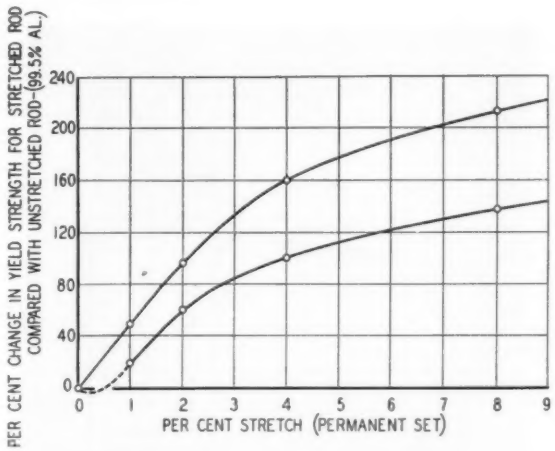

FIG. 7. The effect of stretching on the tensile and compressive yield strengths of aluminum (99.5 percent) rod.

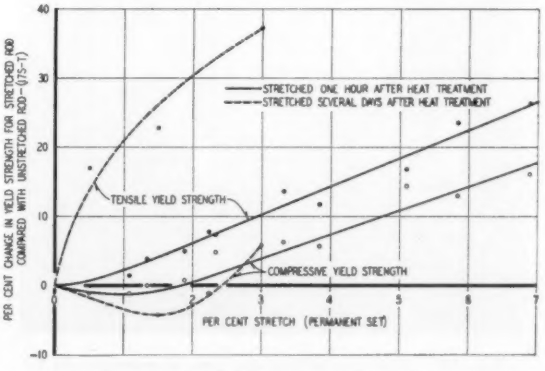
PER CENT CHANGE IN YIELD STRENGTH FOR STRETCHED ROD COMPARED WITH UNSTRETCHED ROD-(17S-T)
STRETCHED ONE HOUR AFTER HEAT TREATMENT
STRETCHED SEVERAL DAYS AFTER HEAT TREATMENT
TENSILE YIELD STRENGTH
COMPRESSIVE YIELD STRENGTH
PER CENT STRETCH (PERMANENT SET)

FIG. 8. The effect of stretching on the tensile and compressive yield strength of 17S-T extruded rod.

Fig. 8 shows that stretching produces a much smaller percentage increase in the tensile yield strength of 17S-T* than was found in the case of the aluminum rod.** Furthermore, there is not a consistent increase in the compressive yield strength of 17S-T but rather an initial slight decrease which seems to be overcome when the percent stretch reaches approximately 2 percent. Beyond this point the curve of increase of compressive yield strength seems to be approximately parallel to that for tensile yield strength. The effect of stretching within one hour after heat treatment appears to be definitely less than the effect of stretching several days later.

Fig. 9 shows that the increase in tensile yield strength with stretching for 24S-T† and the decrease in the compressive yield strength are about the same as for 17S-T, stretched several days after heat treatment. The decrease in compressive yield strength is overcome as the percent stretch reaches a value of approximately 2 percent. The data plotted in Fig. 9 represents four different intervals between heat treating and stretching, namely: 2 hours, 4 hours, 24 hours, and 72 hours. After studying each set of data separately, no consistent trends could be discovered so the entire group of data

* A.S.T.M. Specifications (B89-36T).
** 99.5 percent Aluminum.
† Navy Specification—44T28.

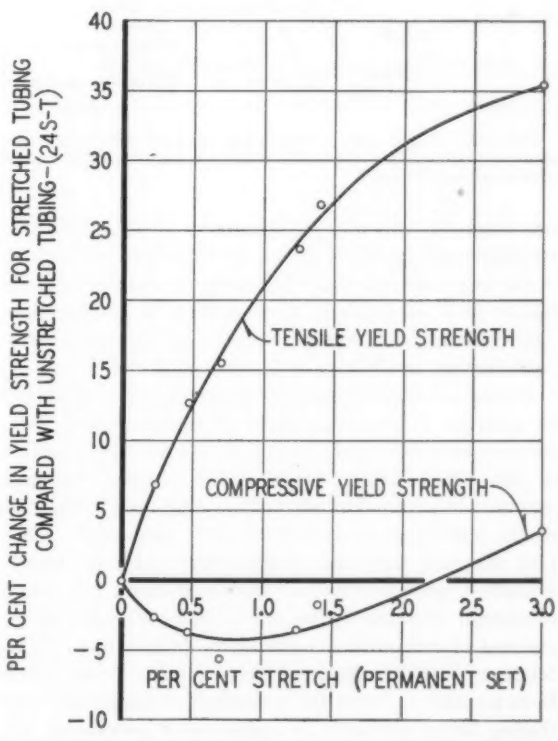

FIG. 9. The effect of stretching on the tensile and compressive yield strengths of 24S-T tubing.

have been plotted together in Fig. 9 ignoring the variation in interval.

The effect of unidirectional cold working produced by the application of compressive forces instead of stretching, is shown by some data obtained in an investigation of 17S-T tubing.* This tubing was divided into three lots, one of which was retained in the condition in which it was received and the other two of which were compressed axially different amounts, the tubing being carefully held in alignment to prevent buckling failures. The tensile and compressive stress-strain curves for the three portions of the tubing are shown in Fig. 10 and display in general the same characteristics as the curves previously discussed, except that the compressive side of the curves has undergone the changes previously noted for the tensile side of the curves. Since the tubing used for this investigation

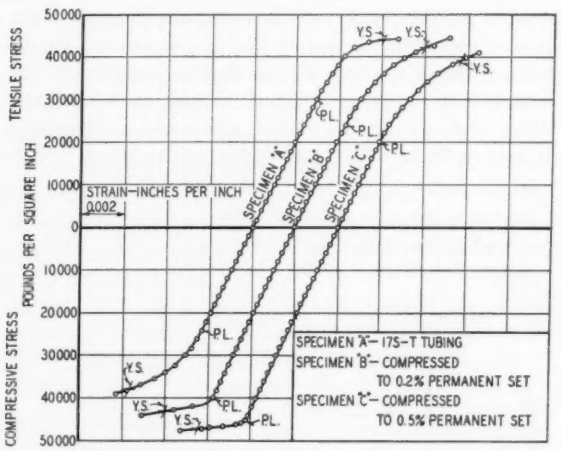

FIG. 10. Tensile and compressive stress-strain curves for aluminum alloy 17S-T tubing showing the effect of unidirectional compressive cold work.

was originally given a slight amount of stretching as a straightening operation after heat treatment, the tubing in the original condition (Specimen A) shows a slightly higher yield strength in tension than in compression. This difference, of course, is reversed by the compressive cold working in the case of Specimens B and C.

Because of the tendency for buckling, it is impractical to produce large percentages of unidirectional compressive cold work, and for this reason the investigation of the 17S-T tubing could not be carried to large amounts of permanent set such as were used in the case of the stretched material previously discussed. This, plus the fact that the original material was slightly stretched, accounts for the fact that there is a slight consistent decrease in the tensile yield strength as the amount of compressive permanent set increases. This tendency would undoubtedly have been overcome had it been possible to carry the investigation further by producing larger amounts of compressive permanent set.

* Federal Specification WW-T-786.

In spite of this tendency, however, it will be noted that there is a consistent increase in the elastic range of the material with increasing compressive cold work.

In order to investigate the effect of cyclic polydirectional cold work on the shape of the tensile stress-strain curve of a metal, an investigation was conducted

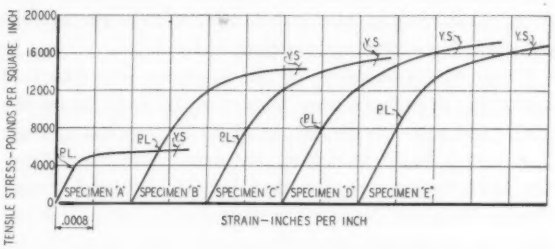

FIG. 11. Tensile stress-strain curves of high purity aluminum rod (99.95 percent aluminum) showing the effect of cyclic polydirectional cold work. Specimen "A"—annealed aluminum rod (99.95 percent aluminum). Specimen "B"—50 percent reduction by cold extrusion. Specimen "C"—stock from specimen "B" upset to original size and shape. Specimen "D"—4th cycle of alternate extrusion and upsetting as above; final step 50 percent reduction by cold extrusion. Specimen "E"—4th cycle of alternate extrusion and upsetting as above; final step upsetting to original size and shape.

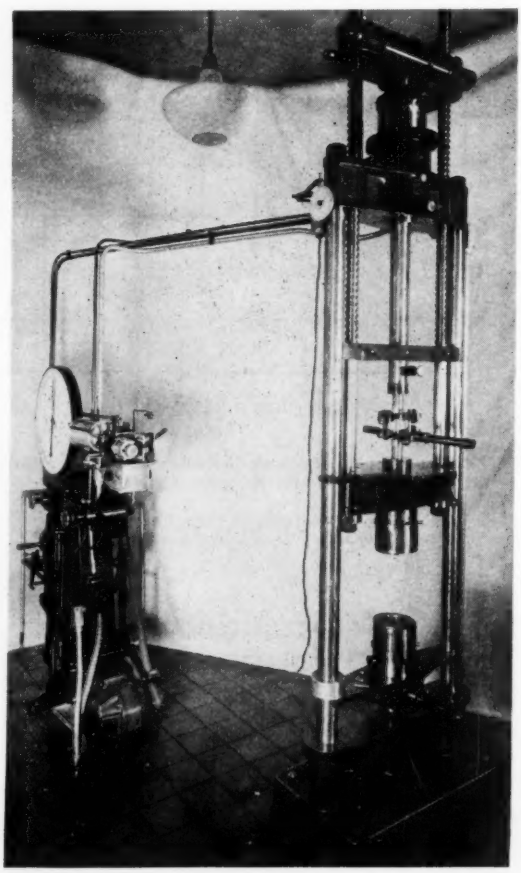

FIG. 12. Testing machine and general arrangement for applying cyclic loads. Specimen shown in position for compressive load.

on some high purity aluminum alloy rod which was first annealed, then reduced 50 percent by cold extrusion, then upset again to its original size and shape, then once more reduced by cold extrusion and so through four complete cycles. The cold working in this case is polydirectional because in each instance the lateral flow of the metal was restrained by the dies and tools used in the extruding and upsetting operations. Tensile specimens were cut from this material at various stages of the operations, and the resulting tensile stress-strain curves are shown in Fig. 11. The enormous increase in tensile yield strength produced by the various operations is evident from a comparison of the curve for the annealed material (Specimen A) with those taken from various states of the cyclic cold working operation. It will also be noted that because of the polydirectional nature of the cold working operations, there is no decided change in the shape of the tensile stress-strain curves whether the specimens are cut from the material following the reduction part of a cycle or the upsetting part of the cycle.

The effects of cold working up to this point of the paper have been shown by separate tension and compression specimens cut from the metal in question at various stages in the cold working operation. This procedure, of course, permits some variation of results because of differences between the various specimens and the different parts of the original lot of material represented by these specimens. In order to eliminate all such differences, it was decided to undertake an investigation in which all of the cold working operations were carried out on a finished specimen suitable for testing either in tension or compression without the removal of the strain measuring apparatus. Fig. 12 shows the testing machine used in this investigation with the specimen in position for the application of compressive stress. To apply tensile stress the specimen was removed to the position below the head and screwed into the spherically seated fixtures. During this shift in position the Ewing extensometer shown in the photograph was left in place.

Fig. 13 shows a cyclic stress-strain curve for an aluminum alloy 17S-T* specimen tested as described above. The set of curves at the left shows the stress cycle beginning in tension and following the usual stress-strain curve up to the point marked A at which point the loading is released and the curve falls off parallel to the initial modulus line crossing the axis of zero stress at a strain of approximately 0.002 in. per in. which marks the amount of permanent set applied in the initial tension cycle. At this point the specimen is shifted to the compressive position in the testing machine and the loading continued so that the compressive part of the stress-strain curve is produced down to the point marked B. At this point the compressive loading is discontinued and the stress-strain curve drops back to the original axis again following the path parallel to the original modulus line. The fact that the curve comes back precisely to the origin indicates no residual permanent set from the first complete cycle of

* A.S.T.M. Specifications (B89-36T).

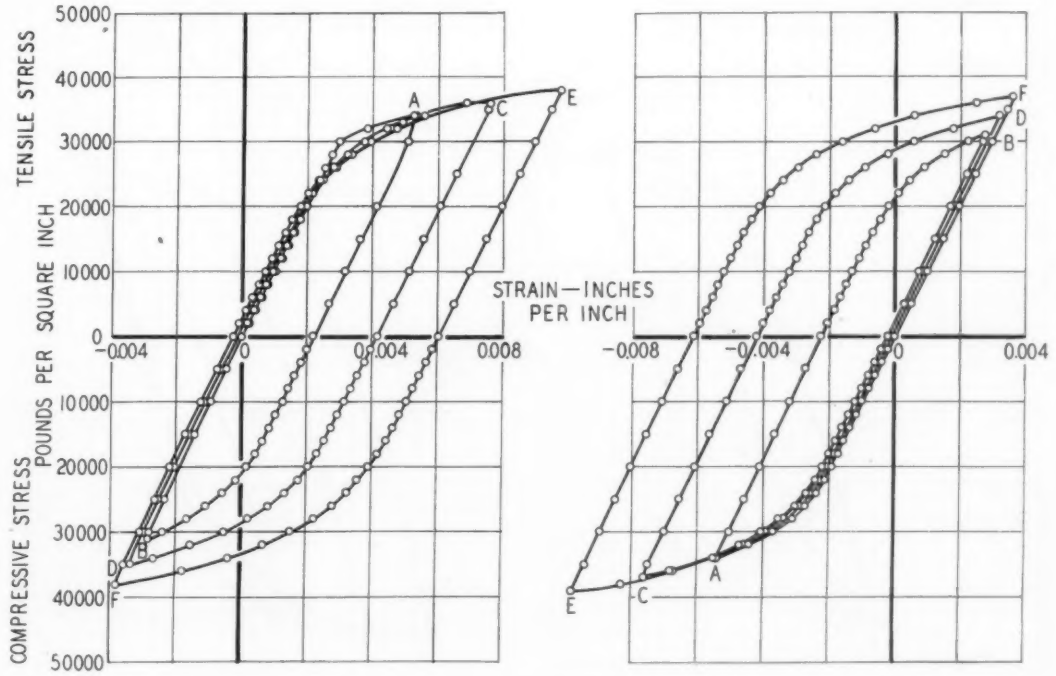

FIG. 13. Cyclic tensile and compressive stress-strain curves of rolled aluminum alloy rod (17S-T).

stress. At this point the specimen is once more shifted to the tension side of the testing machine and the loading carried up to the point marked C, then dropped off, the specimen shifted and loaded in compression to the point marked D, and so on through points E and F, finally returning to zero again with a total permanent set in compression of about 0.003 in. per in. The set of curves on the right side of Fig. 13 is similar except that the original stress cycle is carried out in compression from the origin down to the point marked A, etc.

In studying Fig. 13, it should be appreciated that each set could be broken up into six individual stress-strain curves: three in tension and three in compression. When considered in this manner it should not be overlooked that each of these separate stress-strain curves would be plotted with a new origin differing from that shown in Fig. 13.

The only change in general shape of stress-strain curve indicated in Fig. 13 is found between the first and subsequent applications of tension in the left-hand

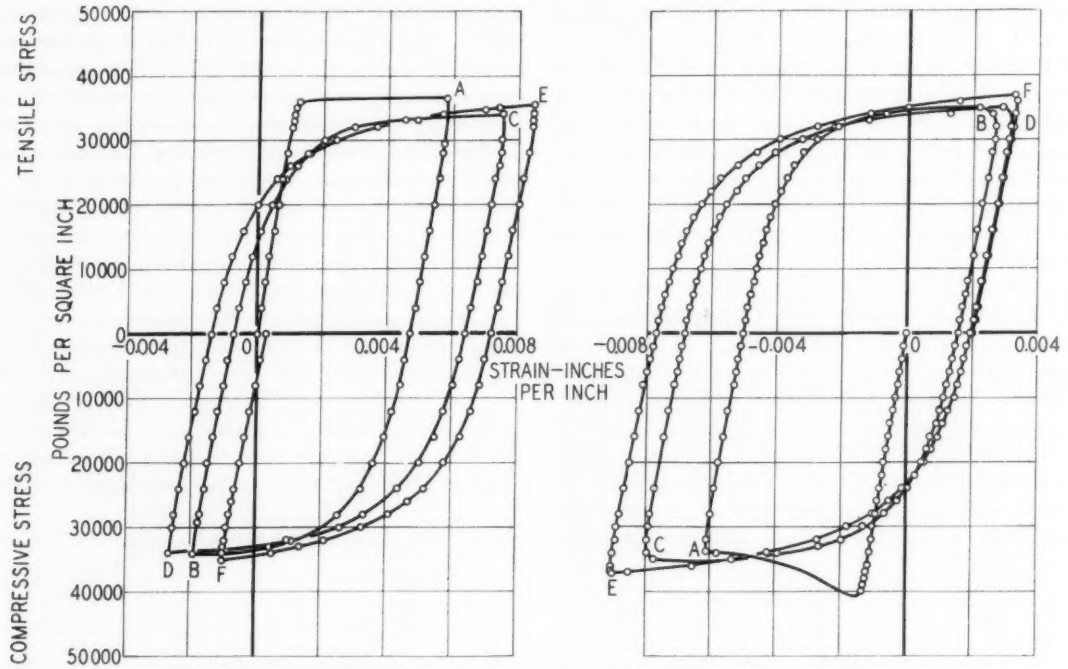

FIG. 14. Cyclic tensile and compressive stress-strain curves for mild steel rod.

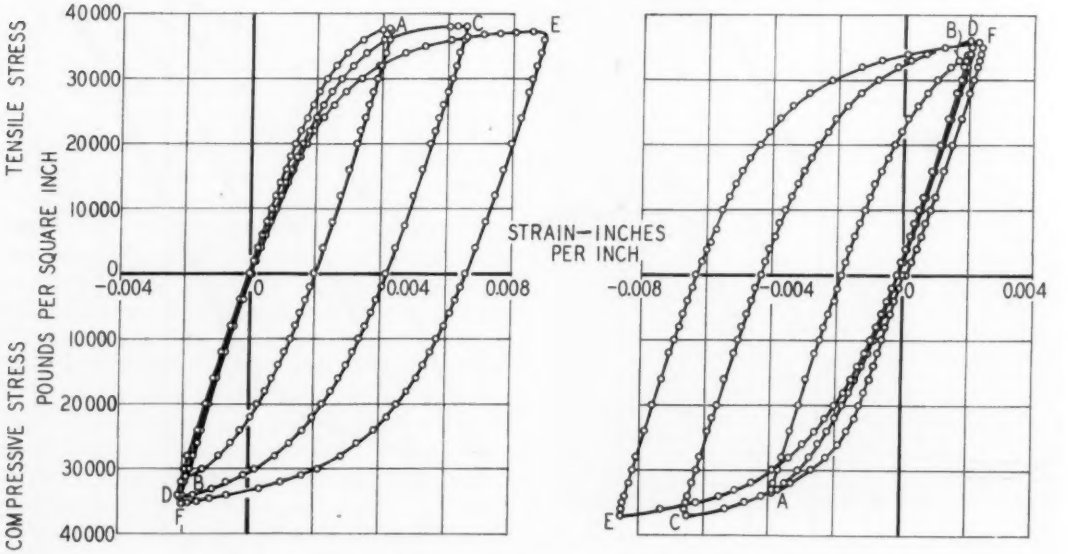

FIG. 15. Cyclic tensile and compressive stress-strain curves for copper rod.

group of curves. The first application of tension shows a slight "knee" in the stress-strain curve which undoubtedly results from the slight amount of stretch-straightening applied to the rod after heat treatment. After one application of compressive stress, however, this disappears entirely and the subsequent curves follow almost identical paths. No such knee appears in the right-hand group of curves because the initial application of stress was in compression, thereby removing the knee before the first application of tensile stress. There is no appreciable change in modulus of elasticity of the material in these curves, and there is no distinct change in the yield strength.

Fig. 14 shows cyclic tensile and compressive stress-strain curves for mild steel* rod and Figs. 15, 16, and 17 show similar sets of curves for copper rod,** brass rod,† and magnesium rod.‡ In the case of the steel rod, the most noticeable characteristic is that the sharp knee at the yield strength appears only in the initial tensile cycle or initial compressive cycle and disappears completely thereafter. In fact, as the cycles of stress proceed, there seems to be a distinct tendency

* S.A.E. No. 1015.
** 99.89 percent Copper.
† A.S.T.M. Specifications (B16-29).
‡ A.S.T.M. Specifications (B107-38T) Alloy No. 8.

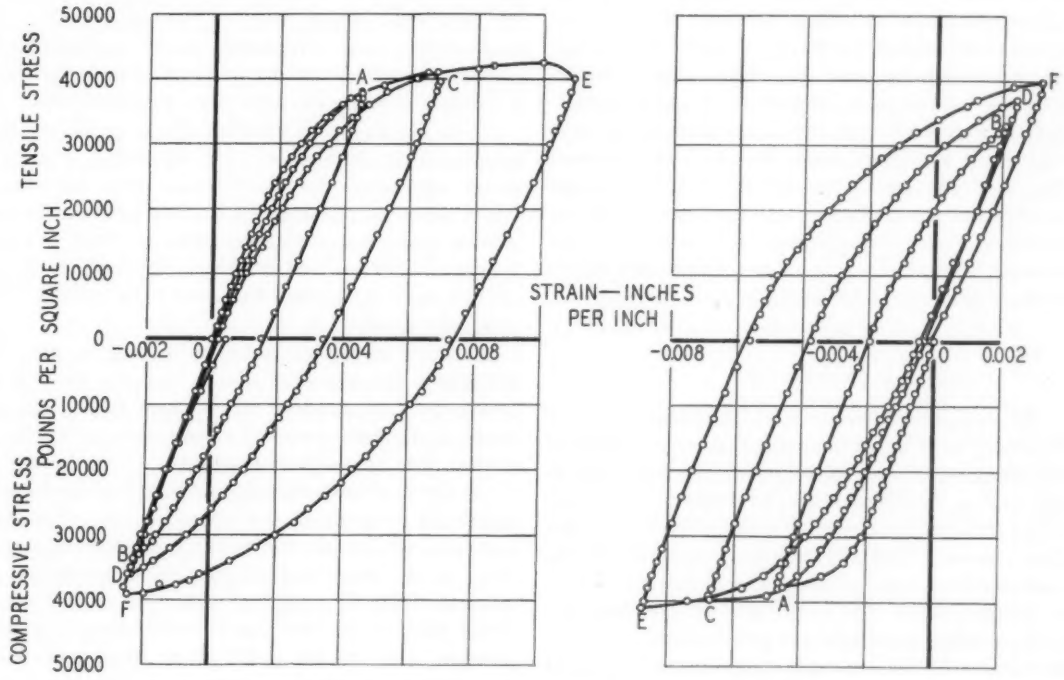

FIG. 16. Cyclic tensile and compressive stress-strain curves for brass rod.

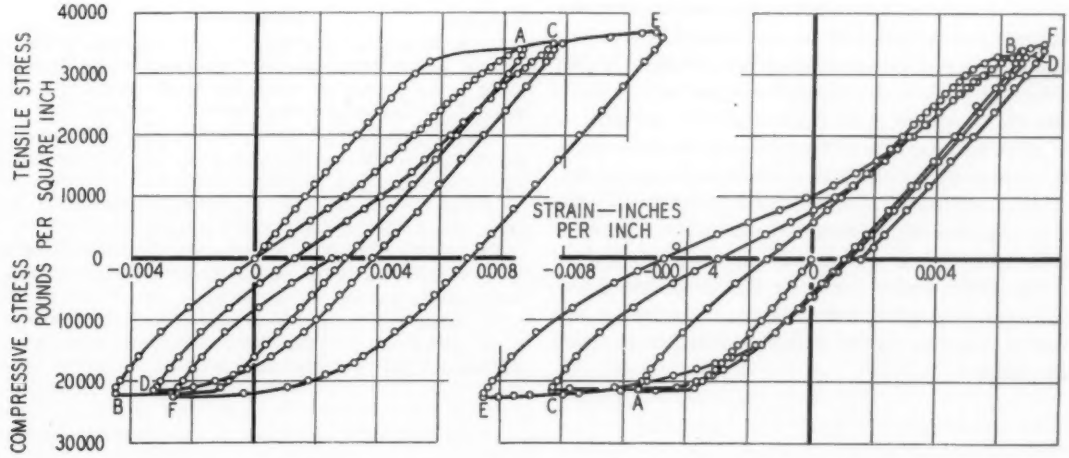

FIG. 17. Cyclic tensile and compressive stress-strain curves for magnesium alloy rod.

to lower the proportional limit of the material practically to zero. In the case of the copper, brass, and magnesium rod, this same lowering of the proportional limit appears and seems to be accompanied by a reduction in the modulus of elasticity of the material. These observations concerning the effect of cyclic stressing or unidirectional cold work upon the modulus of elasticity of various metals is consistent with that reported by Kawai.[2]

The results of the cyclic load tests as illustrated by Figs. 13 to 17, inclusive, show agreement with Dalby's[3] and Bauschinger's[4] results for mild steel but they also show that other materials respond quite differently to cyclic loadings producing unidirectional cold work. McAdam and Mebs[5] show that the shape of the stress-strain curve in tension for stainless steel (18-8) is significantly changed by prior stretching. They give no data on the compressive properties of such material. A study of Figs. 15, 16, and 17 shows that for the copper rod tested, the elastic range decreases with increasing amounts of cyclic cold work but the general shape of the stress-strain curve remains unchanged whereas after several cycles of increasing cyclic cold work the stress-strain curve for the brass and magnesium alloys tested have been radically changed.

Conclusions

(1) An annealed or heat treated metal which has not received any cold working subsequent to the thermal treatment given it, has substantially the same stress-strain curve in compression and in tension. The characteristic stress-strain curve for aluminum alloys in this condition shows a gradually rounded shape above the proportional limit with no sharp knee in the curve.

(2) Unidirectional cold work such as stretching beyond the original yield strength gives dissimilar stress-strain curves in tension and compression, the yield strength being raised higher in the direction of the stress used in producing the cold work.

(3) The characteristic tensile stress-strain curve for aluminum alloys which have been stretched beyond the original yield strength is one which lies distinctly higher than that for the unstretched material and which shows a relatively sharp knee just below the yield strength.

(4) The characteristic compressive stress-strain curve for aluminum alloys which have been subjected to unidirectional cold work by stretching is substantially the same as that for the unstretched material. The compressive stress-strain curve may lie either below or above the stress-strain curve for the unstretched material, depending upon the amount of stretching and the initial condition of the material, whether annealed or heat treated.

(5) The characteristic shape of stress-strain curve for material which has been subjected to unidirectional cold work in compression is just the reverse of that for stretched material, that is, the sharp knee and the large increase in yield strength occurs in the compressive stress-strain curve, while the tensile stress-strain curve retains substantially the same shape as for the material in the condition of zero cold work.

(6) Polydirectional cold working of aluminum alloys, such as is produced by forging, cold rolling, drawing through a die, or extruding, results in tensile and compressive stress-strain curves which lie distinctly above those for the material in the condition of zero cold work but which are substantially the same shape as those for the metal in the condition of zero cold work. The characteristic knee of the stress-strain curve which accompanies unidirectional cold work is entirely absent if the cold working has been truly polydirectional.

(7) In the case of aluminum alloys, cyclic unidirectional cold work produced by subjecting a piece of metal alternately to axial tensile and compressive forces above the elastic range tends to produce the same general stress-strain characteristics as those produced by polydirectional cold working, provided the degrees of cold work in the two halves of each cycle are substantially equal.

(8) Cyclic unidirectional cold working of mild steel eliminates the characteristic yield point in both the tensile and compressive stress-strain curve and produces a gradually rounded stress-strain curve similar to that of most non-ferrous metals.

(9) Cyclic unidirectional cold working produces no significant changes in the shape of the stress-strain curves of the copper rod tested but completely alters those of the brass and magnesium alloys tested. In all cases there is a marked reduction in the proportional limit of the material in both tension and compression, often to the point where there is no longer any initial straight-line portion of the stress-strain curve.

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[1] L. B. Tuckerman's method. See his discussion of the paper entitled *The Determination and Significance of the Proportional Limit in the Testing of Metals*, by R. L. Templin, A.S.T.M. Proceedings, Vol. 29, Part II, 1929.

[2] Kawai, Tadashi, *The Effect of Cold Working on Young's Modulus of Elasticity*, Science Reports of the Tohoku Imperial University, Sendai, Japan, Vol. XIX, 1930.

[3] Dalby, *Strength and Structure of Steel and Other Metals;* Longmans, Green and Company, New York, page 144.

[4] Bauschinger, *Die Vernaderungen der Elasticitätsgrenze*, Mitt. a. d. Mech. Tech. Lab. (München) 1886. See also Dinglers Polytechnical Journal, Vol. 266, 1887.

[5] McAdam and Mebs, *Tensile Elastic Properties of 18:8 Chromium-Nickel Steel as Affected by Plastic Deformation*, N.A.C.A. Technical Report No. 670, 1939.

Flightray, a Multiple Instrument Indicator

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Sperry Gyroscope Company

ABSTRACT

The present paper is a progress report on the development of an instrument by means of which the information from those flight instruments constantly requiring the pilot's attention is concentrated into an easily readable diagram on the fluorescent window of a cathode ray tube. Attitude and positional information and air speed are shown diagrammatically. A switching arrangement couples each primary flight instrument in turn to the cathode ray tube. The switching is carried out at a rate well above the threshold frequency so that the image gives for all practical purposes a continuous picture of the movements of the airplane as shown by the actuating instruments. The arrangement of the information, flight tests, and various problems encountered in the development along with their tentative solutions are described.

THE PILOT'S INSTRUMENT PROBLEM

Introduction

THE modern aircraft has as its nerve-center an extremely complex array of instruments which literally fill the cockpit. Since the efficiency and safety of flight is dependent upon the information which the pilot has concerning the functioning of his equipment, the attitude of his ship and his location, this profusion of instruments is highly desirable. On the other hand, although the instruments are arranged in as orderly a manner as the small space allows, there are so many instruments and so many types of information necessary that even the most experienced pilots complain of mental confusion.

Automatic Operations

The first and most logical method of simplification is to convert some of the pilot's manual controls to automatic operations. The automatic pilot, automatic mixture controls, propeller pitch control, carburetor heat control, etc., are all new additions to the modern airplane that have greatly relieved the pilot. The list is expanding rapidly, and it is felt that many more automatic operations can be utilized profitably in the future. But it must be remembered that, although automatics relieve the pilot of manual duties and make it unnecessary for him to watch many of the instruments continuously, it does not relieve him of the *responsibility* for their functioning. Hence monitoring instruments still must remain in view for him to check and the total number of instruments is not reduced.

Division of Duties

Another practical method of alleviating the pilot's problems is to increase the crew and divide the duties among them. Complete apportionment of all duties is practical only on larger aircraft, and in the large transports, both for ocean and land flying, this solution is imperative. A flight engineer takes over all engine instruments and their controls. Radio and navigation are departmentalized and placed in the hands of additional crew members. Thus the pilot is free to concentrate on the flight instruments.

Coordination of Flight Instruments

Most of the important flight instruments are now available and the time has come when reconsideration of the whole problem of arrangement can take place. It is felt that such reconsideration is quite important, and this paper presents a progress report of studies and experimental work undertaken by the Sperry Gyroscope Company, directed toward the coordination of flight instruments. The object of the experiments is *to provide a single indicating instrument which will show on its face all necessary flight information in the most easily interpretable manner.* The problem may appear to be relatively simple, but it has taken four years of continual experimenting and testing to solve it even partially. The objective as stated involves two questions which must be decided: first, what shall be the physical method or instrument on which the indications can be combined; second, what pattern of indications can show the necessary information in an "easily interpretable manner?"

The National Air Transport Company in 1926 made one of the first attempts at coordinating the flight in-

Presented at the Instruments Session, Eighth Annual Meeting, I.Ae.S., New York, January 25, 1940.

The authors acknowledge their indebtedness to the following men and organizations, whose contributions to the development of the apparatus have been considerable. Many military and airline pilots flew the equipment and made suggestions, some of which were incorporated in the present arrangement. The United Air Lines, the Bendix Radio Corporation, the Civil Aeronautics Authority, and the RCA Manufacturing Company cooperated in the carrying out of flight tests. The interchange of information with Prof. E. L. Bowles and Prof. C. S. Draper of the Massachusetts Institute of Technology, who during the same period have been carrying on the development of the C.A.A.-M.I.T. Instrument Landing System,[4] has been very helpful. F. L. Moseley of Aeronautical Radio, Inc., who has been the greatest contributor to the Flightray and who was in charge of the project during the first two years of its development, has continued to be of great help in its furtherance.

struments by mounting them so that their indicating pointers formed a pattern when all conditions were normal. It was relatively easy for the pilot to note the deviation of any single instrument from the pattern. But the scheme was cumbersome and not adaptable to all instrument boards. Divergent ideas on arrangement and various shapes of instrument boards have prevented standardization. Mechanical combinations of instruments have also been tried. From two to five instrument movements have been crowded into single cases in various attempts at multiple indication on one face, but all of these experiments have been condemned on two counts; first, the pilots were confused by the indications of multiple unrelated pointers on the same face, and second, the maintenance problem necessitated the removal and handling of all instruments when any one of the combination required attention.

Multiple Instrument Indications

The Cathode Ray Tube as an Indicator

In the present approach to the problem, the cathode ray tube was selected as the instrument most readily adaptable to the problem of combining a number of indications on a single face. Its extreme flexibility as an indicator has become well known through its widespread use as an oscillograph. Several other experimenters have reported on cathode ray tubes as indicators in airplanes.[1,2,3,4] The particular advantage in the present case is that the tube allows a wide variety of indications from which a suitable combination could be chosen. By the simple expedient of commutating, it was possible to produce multiple indications of widely different form, without mutual interference. As the tube was being used to assemble flight instrument indications, the term "Flightray" was suggested and adopted as an appropriate name for the complete system.

By the use of the cathode ray tube, it has been possible to set up and actually try in flight and landing tests a great variety of schemes. No other means is known which would allow the extreme latitude of selection of ideas which the cathode ray tube has permitted.

Arrangement of First Model

The first approach to the selection of a pattern was made on the following premises: First, flight instruments of primary importance, *i.e.*, those which need the pilot's continuous attention, must be selected for indication, and must, therefore, be concentrated in the "attention area." Second, the indications of each item must be so different that there can be no confusion such as that which results from a multiplicity of instrument hands. Third, in the interests of simplicity, scales and numerals should be eliminated as far as possible.

Attitude Information

Attitude indication by duplication of the horizon bar on the cathode ray tube presented no problem. Its universal motion of up or down for dive or climb and tilting for banking indication was easily transposed to the horizontal cathode ray trace. The turn indicator was selected to show performance about the azimuth or vertical axis. It was transposed from a standard Pioneer turn indicator to the Flightray face, causing a vertical line or trace to be deflected laterally in proportion to the rate of turn. These two lines crossing each other normally at right angles through the center of the face made a very satisfactory blind flying instrument. The next problem was the directional gyro. It was thought best to have full 360° indication by marking the periphery of the tube with an azimuth scale and indicating course by a short luminous radial line movable around the periphery of the tube with change of angle. Flight tests showed that this arrangement was confusing and, further, that full azimuth indication was not necessary.

Positional Information

The indications so far described give all of the necessary information regarding the angular position of the airplane with respect to the X, Y, and Z axes. For flying a definite path, however, additional indications must be made to show the location of the airplane with respect to the path. In the case of blind landing, this is the most important function of the instrument. In order to add path indication without confusing it with the angular position indications, a circle was selected as the indicator. The circle is arranged so that it may be deflected to the right or left by departure from a radio localizer path, and up or down to indicate departure from the glide path of the radio approach glide beam. The circle, therefore, can move anywhere over the face of the instrument, but must be brought to the center of the instrument for normal or "on path" indication. A black bull's-eye was painted on the center of the face of the instrument so that the path location ring might encircle it and the horizontal and vertical attitude lines might cross through it when everything was normal.

Flight Tests

The first Flightray model embodying the above ideas was built in the spring of 1937, and was tested in a Link Trainer. All observers agreed that the combination on a single face of the various instrument readings aided materially in the control of the Trainer. This was especially apparent to those who had no previous experience in flying the Trainer. Another favorable comment on the first instrument was that the green color of the pattern was pleasing to the eye. The apparatus was then put into condition for actual flights on an instrument landing system, where the problem of instrumentation is most acute.

Several months of flying and landing tests were made during the summer of 1937 at Indianapolis Airport. About two hundred instrument approaches were made, utilizing the Department of Commerce instrument landing system which had just been installed there. Many found it easy to learn to use the Flightray, and most comments were very favorable, but many changes in the pattern arrangement were suggested as a result of these tests. The final result of such suggestions was a considerably modified viewpoint regarding the manner in which the information should be shown. Although this new viewpoint may at first appear to be a relatively minor modification to the indicator, it has had considerable effect on the progress of development. It is simply that information should be conveyed to the pilot in as nearly a pictorial manner as possible, without too much emphasis on the original appearance of the instrument to be indicated.

Arrangement of Second Model

Attitude Information

Pictorial portrayal of information requires, first, that a miniature airplane be silhouetted in the center of the screen to replace the bull's-eye originally employed, and second, that the miniature airplane be "flown" in relation to the luminous traces shown on the screen. With the artificial horizon, this technique is well known. The new suggested technique is an extension of the same principle to all Flightray indications. In order to bring the airplane back to a normal attitude, position or heading, the miniature airplane is flown toward *any* of the luminous lines. (See Fig. 1.)

In following out this principle, the first change made was the elimination of the rate of turn indicator. This instrument had been indicated as a vertical line moving laterally to indicate rate. The horizontal line from the gyro horizon indicated amount. It was found confusing to have a rate and an amount indication crossing each other. Furthermore, the experienced airline pilots who flew with the instrument found they did not need rate of turn indication and that its relatively more active movements were distracting.

To take the place of the rate of turn vertical indication, the directional gyro line was substituted. As mentioned previously, the 360° radial indication of direction was found unsatisfactory, so it was converted into a short vertical line which moved laterally, right or left, to indicate amount of change of azimuth. This made directional gyro and artificial horizon indications conform in behavior to the horizontal attitude axes indications; both show the amount of change of *attitude*.*

* The directional indication now shows only a limited segment of azimuth—plus or minus 20° having been chosen. Because of this limited motion, it is therefore now necessary to set in large changes of course by hand in order to centralize the azimuth indication, but the change has been found to be justified because it prevents confusion of indications.

There is one method of azimuth indication which has been tested extensively and proved to have particular merit. This is the use of a radio compass for heading indication while making an instrument landing. Further tests of the radio compass are planned, as it is felt its use as a homing device is valuable not only for instrument approaches and landings, but for route flying as well.

Positional Information

What may be called the path location circle on the Flightray has not only complete freedom of movement about the screen but can be made to indicate from a choice of several instruments. In cruising flight, for example, it is deflected up or down by the barometric altimeter and thus indicates level flight.† The sensing of the circle motion has been chosen to be consistent with the ideas of pictorial representation. In other words, the miniature airplane is flown *toward* the indication. Thus, if the circle is seen to be below the fuselage of the miniature airplane, then the nose of the miniature airplane is pointed down by moving forward on the control of the real airplane. The horizontal line rises above the fuselage and is held at a definite

† When two-course U.H.F. ranges are installed along the airlines, the horizontal component of the motion of this circle will serve admirably to indicate the position of the beam, and the two motions will combine to indicate flight path.

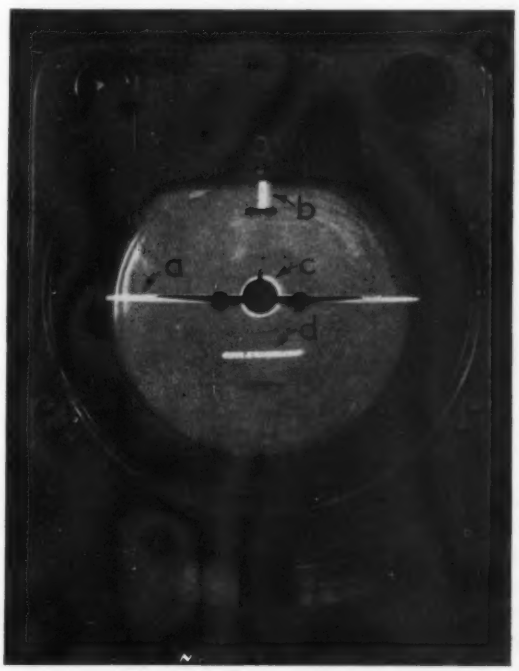

FIG. 1. Flightray indicator. a is the artificial horizon, b the directional gyro, c the path location circle, and d the air speed meter. Purple and amber marker lights are in the upper corners; the ball bank indicator is below the center.

point until the aircraft has climbed sufficiently to reach the set altitude, when the circle will surround the fuselage of the miniature airplane. Just as the circle is approaching the center position, the control should be pulled back so that the horizon line is again cutting the center of the fuselage. In this way, the two indications will reach the central position simultaneously and no oscillation or "hunting" will take place.

When the path location circle is used in making instrument landings, both horizontal and vertical components of motion are utilized. The localizer landing beam is arranged to control horizontal motion of the circle and glide beam controls the vertical motion of the circle.

To illustrate the use of the circle in a landing operation, say that the circle is below and to the left of the miniature airplane, as shown in Fig. 2. In this case,

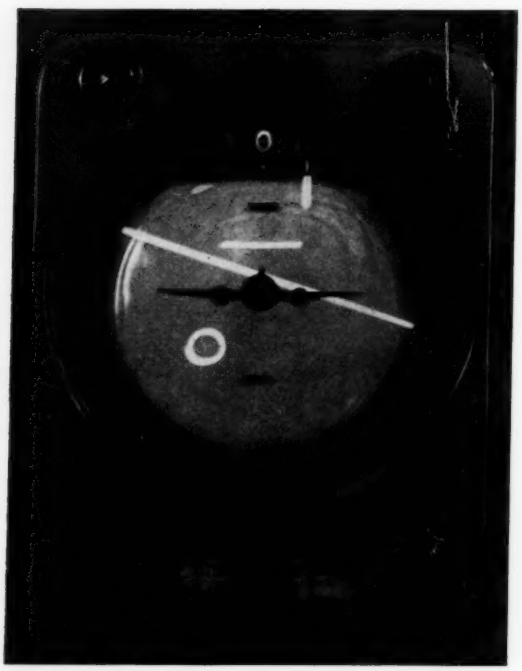

FIG. 2. Flightray indicator. Appearance of pattern while executing maneuver described in the text.

the control is moved forward in exactly the same manner as when setting on altitude, though the circle is no longer actuated by a barometric altimeter, but, instead, by a vertical radio glide path. Left rudder and down elevator are applied simultaneously and, assuming that the directional gyro has been set to the runway heading, the directional indicating vertical line will move to the right and should be held steady at some arbitrary position, say 10°. The circle will drift slowly directly toward the center of the screen, and, just prior to actual "ringing" the fuselage, both the directional gyro and the artificial horizon lines are centralized.* The aircraft will then be exactly on the glide and localizer paths with the elevational and azimuthal heading correctly determined for *remaining* on the combined path.

In making instrument approaches or instrument landings, air speed was found to be of sufficient importance to rate a place on the Flightray. As a protection against approaching stall conditions, experienced pilots have demanded its addition. It is difficult to add air speed to the Flightray face so that it conforms to the pictorial pattern theory. After trying a number of arrangements, however, a short horizontal line which rises across the face of the instrument with increasing air speed was selected. When this air speed line is at the middle of the face, air speed is normal. As the line sinks toward the bottom of the face, stalling conditions are approached. A black mark on the lower portion of the face is added as a check point or warning mark.

For marker information, either for route flying or instrument landing procedure, two marker lights are provided which are mounted above and to the left and the right of the cathode ray tube screen. Being mounted so close to the center of interest, they are readily visible without distracting from the attention which must necessarily be devoted to the center of the screen. A ball bank indicator is placed just below the cathode ray tube screen. The ball bank indicator is necessary as it is only by its use that the proper degree of bank can be maintained for any given rate of turn. This instrument is so simple and so easily mounted that it was not considered worthwhile to show its indication by means of a cathode ray tube luminous line.

Second Flight Tests

When apparatus had been constructed to conform to the ideas suggested by the first flight tests, a three months' period of testing was begun in 1938 at Newark. Here the facilities of the Bendix Aviation Corporation and United Airlines were made available and many wheel contact landings demonstrated successfully.

APPARATUS DEVELOPMENT

A schematic diagram of the primary instruments and the Flightray indicator is shown in Fig. 3.

The Cathode Ray Tube

Desired patterns are drawn on the screen by electrostatic deflection of a pencil beam of electrons with the tube. Wherever this pencil of electrons strikes the screen, the fluorescent material of which the screen is composed becomes luminous. In order to produce a line or a circle, an alternating voltage is applied to either vertical or horizontal deflection plates in the correct phase relationship to cause the spot to trace

* In flying this indication, it is easiest to think of the circle as the cross-section of a tube, down which the airplane is flown.

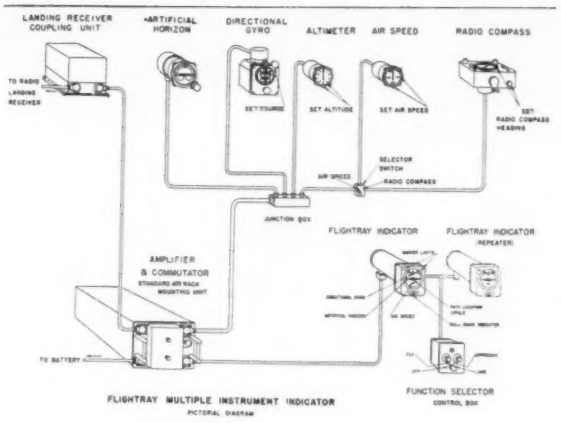

FIG. 3.

out the desired figure. Each instrument has attached to it a signal pick-up so constructed that no appreciable power is taken from the instrument. When this pick-up is centrally located relative to two stationary elements, no deflection voltage is applied to the cathode ray tube beam. However, if the instrument deviates from the normally set-in position, a differential alternating voltage is produced which, when rectified and amplified, is applied to deflect the desired pattern on the face of the cathode ray tube. Since there are four separate indications on the face of the Flightray, switching is necessary. To accomplish this, the various amplifiers associated with each instrument pick-up are sequentially made operative by means of a commutator which applies suitable control voltages to each amplifier in turn. Commutation takes place at a rate well above the persistance of human vision with the result that, though only one line is shown at a time, the resulting pattern is entirely free from flicker.

Signal Pick-Off Device

During the course of the Flightray development, capacitive pick-up was used for providing deflection voltages from a wide variety of instruments. However, because of the short connecting leads required, it has not been found practical to pick up indications from instruments located remotely from the vacuum tube amplifier equipment. During experimental work, when it was expedient to have a single equipment unit which could be installed and removed quickly from any aircraft, no disadvantage resulted. When permanent installations are contemplated, it is desirable to dissociate the signal instruments from the vacuum tube amplifiers so that the former may be mounted wherever desired. Accordingly, capacitive pick-up has been abandoned recently in favor of simple electro-magnetic type of pick-up which permits remote location of instruments.

The new electro-magnetic pick-up is an application of the miniature Telegon a.c. selsyn, developed recently for remote indication purposes by the Kollsman Instrument Company.[5] When used for supplying deflection voltages for Flightray patterns, only the transmitter element is employed. A balanced diode rectifier delivers the necessary d.c. to the commutated vertical or horizontal amplifiers. The Telegon is small, light, exhibits negligible coercive force, and is readily applied to existing flight instruments. Because the device operates at low audio frequencies, placement of signal instruments is unrestricted by lead length and they can therefore be located anywhere on the aircraft. Fig. 4 is a photograph of the instruments with the pick-off units attached.

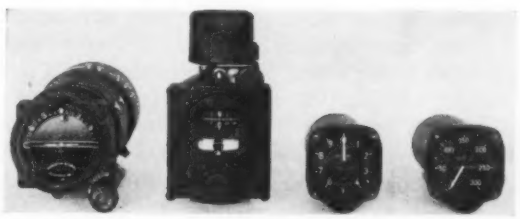

FIG. 4. Instruments with pick-off Telegon devices attached.

Freedom of apparatus location permits the signal instruments to be mounted on the flight panel, where they serve to prevent duplication of flight instrument equipment on board the aircraft. Being entirely unaffected by the addition of the pick-up device, they then become the stand-by instruments. The instruments are provided with setting dials—thus allowing the entire flight picture to be set up on the instrument panel in the same way as with the automatic pilot.*

Power Supply

The cathode ray power supply is unusual in that a high impedance source of direct current at 2000 volts is required. This voltage is obtained from a small dynamotor running from the aircraft's normal 12 or 24 volt battery system. The dynamotor does not supply the high voltage directly but supplies an a.c. which is then transformed and rectified for the operation of the cathode ray tube. The same machine also supplies d.c. for the amplifiers as well as a.c. for drawing the various pattern lines. Total power requirements, originally unreasonably high at 240 watts, have been gradually reduced to less than 100 watts.

Commutation

The search for a satisfactory means for commutating the four pattern signals was one of the most difficult features of the development. These patterns are placed on the screen in sequence and at a rate well above the threshold of visible flicker. However, since this thresh-

* As an example, the air speed indicator tracter dial may be set to 140 m.p.h., altitude to 4000 feet, directional gyro 230°. The primary instruments are then disregarded and all flight maintained by reference to the Flightray indicator—without thought to numbers.

old increases in frequency with increased pattern brilliance (and high brilliance is required for sunlit cockpit conditions) commutation rates of less than 30 cycles per second are objectionable. In fact, a frequency of nearly 60 cycles is desirable. However, frequencies this high impose many design specifications which are especially severe, due to the high order of reliability which must be maintained.

No less than seven types of commutators have been thoroughly investigated. One of the most promising of these has been an electronic commutator, which has had much service testing and has been found satisfactory except for high power requirements and circuit complexity. Lately, however, a new type of mechanical switch which provides both commutation and return trace blanking voltages has been adopted. This device is simple and on life tests has proved to be thoroughly reliable. Although work on other types of commutators is still in progress, it is felt that this newer development will serve for some time to come. Fig. 5 is a simplified wiring diagram of the apparatus.

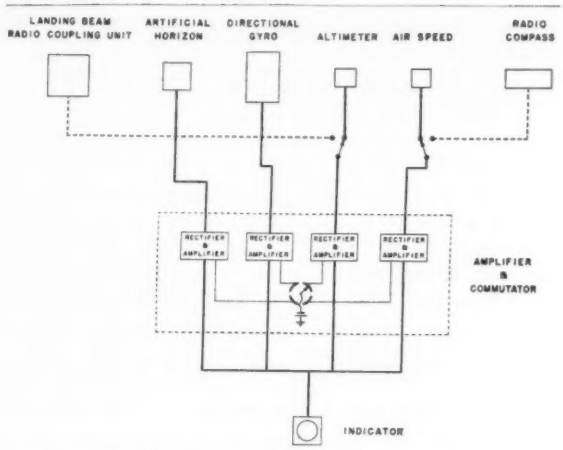

FIG. 5. Simplified electrical diagram. (Return trace blanking switch not shown.)

CONCLUSION

When studies of multiple indications were first begun, it was thought that the Flightray might prove only a very useful laboratory tool with which to explore the problem of aircraft instrumentation. However, as time has gone on and technique improved, the cathode ray method of instrument indication has proved decidedly valuable in itself. It was at first thought that pilots would object to the luminous lines; that eyestrain, contrast, unsteadiness, etc., would be serious drawbacks. However, this has not proved to be the case. Many pilots have flown with the instrument and the general reaction has been favorable. Pilots have found the fluorescent pattern, with its rather soft green color, quite different from other objects on the instrument board, so that it tends to stand out and become the most striking feature of the surroundings, either by day or night.

Much preliminary flight testing has been done. Circuit and electrical apparatus have reached an advanced stage of development. The general theory and practical applications of multiple indications have been sketched roughly. The work which is here reported is still incomplete, but it was considered that enough had been accomplished to warrant presentation of a progress report at this time.

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Book Review

The World of Wings and Things, by SIR ALLIOTT VERDON-ROE; Hurst and Blackett, London, 1939; 270 pages, 7s. 6d.

The name of Sir Alliott Verdon-Roe stands well up in the list of the first dozen of aviation pioneers. He taught himself to fly and built and piloted the first English airplane, on June 8, 1908. If his career had stopped there he would have made a place for himself in aeronautical history, but for thirty years he has continued to design and manufacture outstanding types of aircraft. His famous 504 was the standard British training plane and more than twenty thousand were built.

This autobiography will be an inspiration to young people and pleasant reading for "A. V.'s" many friends. The story of his life belies those pessimists who are dubious about the rewards that inventors receive.

"A. V." is best known for his aviation activities. It will surprise many to read the chapter, "Many Inventions," and realize the wide scope of his inventive genius.

Combined with a gentle nature which has won him many friends in all parts of the world, is the strong spirit of the crusader. For many years he has been propounding a scheme for currency reform which is as radical as might be expected from one who persisted in building early flying machines. His views on world affairs, which he states frankly, are those of an independent individualist.

As history the book is priceless and as a record of achievement it is outstanding.

Brittle Lacquers as an Aid to Stress Analysis

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ABSTRACT

The fracture of brittle coatings has long been recognized as a method of checking strain distribution. Flaking of brittle mill scale at the yield point of local areas was used in the testing of the first wrought-iron bridges. More recently brittle resin coatings which will fracture within the elastic range of most materials have been developed to give good qualitative pictures of strain distributions.

The present work describes an improved brittle coating in the form of a sprayable lacquer which air-dries over night to form a coating of uniform brittleness within the limits of thickness of three to eight-thousandths of an inch. A calibration method is described whereby quantitative values of strain may be estimated within fifteen percent.

INTRODUCTION

ENGINEERING structures are designed to transmit loads. The basis of the design is two sets of assumptions, the loads to be carried and the manner in which these loads flow through the structure. From consideration of the assumptions of distribution the shape and materials of the design are derived.

The primary role of stress analysis is to check a design for the distribution of the forces carried. In many cases a number of alternative designs are available and the best or the cheapest is to be selected. To aid in this check, loads, simulating service conditions, often are applied to the structure and strains measured over critical areas.

Convenient mechanical or optical strain gages can be used down to about one-half inch gage length, but cannot be readily applied to fillets, curved surfaces, and inaccessible regions. They are further handicapped by the number of separate measurements that must be made at different points and in different directions, in order to be reasonably certain that the critical strains are located.

The perfect strain gage might be thought of as one which would simultaneously give an infinite number of readings of infinitesimal gage length over the entire surface of the structure. Brittle coatings under proper control approximate this ideal. While not as precise as mechanical gages, they furnish an excellent overall survey with sufficient accuracy for most engineering purposes.

HISTORY OF BRITTLE COATINGS

It has long been recognized that a brittle coating on strained metal parts furnishes an excellent means of recognizing overloaded regions. Since the days of wrought-iron bridges the cracking of the brittle oxide scale present on hot-rolled or annealed steel has been used to indicate local yielding. Whitewash over the scale has been used for many years as a special method to increase the visibility of the cracks.

Attempts to use a varnish, lacquer, or hot-applied resin coat, which would crack at values of strain within the elastic range, were published in 1932[1] and 1934.[2] In 1937, a more complete study of brittle lacquer behavior was started by the junior author with the active support of E. S. Taylor.[3] That and more recent work under the supervision of the senior author have resulted in the removal of several limitations previously encountered.

PROPERTIES OF BRITTLE COATINGS

A broad definition of a brittle coating is one which will fracture in response to strain in the structure beneath it. Brittle oxide scale cracks and flakes in an irregular pattern when the metal beneath it yields. It indicates areas of high local strain.

To indicate the direction of strain, the brittle coating needs the additional property that it will adhere to the surface of the structure while it fractures within itself. Hot resin coats will do this and so provide qualitative pictures of areas of maximum tensile strains and their directions, the cracks running normal to the principal tension strain.

Quantitative measurements require, in addition, that the coating be uniformly brittle over the entire surface of the structure and possibly also over some calibration model. For practical use the coating must be uniformly brittle over a range of thickness since the other alternative, uniformity of thickness, is difficult to attain.

The brittle coatings developed at M.I.T. are in the form of air-drying lacquers which may be sprayed on, dried over night, and used the next day. These coatings are to a practical degree uniformly brittle within the thickness range of three to eight-thousandths of an inch.

Under normal conditions of use, the coatings begin to fracture with about 0.0007 in. per in. strain and produce a recognizable variation of crack pattern up to about 0.0012 in. per in. strain. In terms of stress on steel these values are: starting fracture at about 20,000 lb. per sq.in. and change of pattern up to about 35,000 lb. per sq.in. When strains increase above the upper limit,

Presented at the Structures Session, Eighth Annual Meeting, I.Ae.S., January 25, 1940.

the crack patterns increase in number and regularity so slowly that the recognition of the amount of strain they represent becomes difficult. The sensitivity of the coatings may be increased by temperature manipulation. For instance, a coating dried at 75°F. and tested at 68°F. would start to fracture at about 15,000 lb. per sq.in. stress on steel.

The spacing of the cracks in a well-filled pattern has been found to be a function of the thickness of the coating, with the distance between cracks averaging five times the thickness of the brittle film. It is believed that this phenomenon indicates that fracture initiates at the free upper surface of the coating. This conclusion is further substantiated by the facts that surface finish is of negligible effect on the sensitivity of the brittle coatings and that thin sections in bending cause the coating to crack at lower values of structure surface strains than occur with straight tension loading.

Rate of loading appears to be of little effect, provided maximum load is reached within ten minutes. Since considerable time is usually required for inspecting new crack formations during loading, a convenient schedule is to load until a general inspection is desired; return the load to zero during the inspection, and then reload.

Several rough checks appear to indicate that the coatings react normally at high rates of loading, even into the impact range. However, more exact measurements will have to be made before it is certain that the strain sensitivity remains fixed.

Atmospheric conditions of temperature and humidity have been found to affect the lacquers. In order to obtain satisfactory results under different conditions it has been necessary to formulate a graduated series of brittle lacquers, and, by means of a chart, pick the correct one for the prevailing temperature and humidity. After being painted, the coating should not be subjected during drying to a sudden temperature variation of more than 5°F., nor to a slowly acting change of more than 10°F. During testing, temperature variation should be less. Humidity ordinarily does not change enough to cause trouble.

Use of the Brittle Coatings in Strain Analysis

The brittle coating may be thought of as providing a large number of principal tension strain indicators with a minimum gage length of the order of 0.05 inch and with a workable range of approximately 0.0007 to 0.0012 in. per in. strain.

Quantitative evaluation of the amount of strain is secured by calibration. A calibration strip at the left in Fig. 3, is sprayed and dried along with the structure under test. When ready the strip is given a known loading as a cantilever beam in the calibrator, as shown in Fig. 2, and then placed in a scale marked with the values of strain the calibration strip has received. Evaluation of the strains on the structure is made by matching the regularity of the crack patterns on the structure and on the calibration strip rather than counting the number of lines per inch.

Since the range of strain which can be evaluated is smaller than the range present on most structures, another principle must be utilized in order to effect a complete analysis. If the assumption is made that Hooke's Law holds over the entire structure, then local strains at different values of loading on the structure can be measured and by simple proportion one can interpolate or extrapolate all local strains to correspond to any value of loading chosen. In general, Hooke's Law is a good approximation to actual performance and, in practice, structures which seriously deviate from it are fairly easy to recognize.

While the brittle coating is unaffected by compression strains as such, nevertheless it is possible to evaluate them by causing the coating to fracture from the relaxation of a compression strain. The procedure is to place an elastic structure under maximum load and then form the brittle coating on its surface. At the same time, a calibration strip is placed under load in the calibrator with its coated surface under compression. The test is run by relaxing the loads from their maximums both on the calibration strip and on the structure in a manner very similar to the evaluation of tensile strains by the addition of loads.

On areas of moderate strain concentration, values of principal tension and compression strains may be estimated within an error of about 15 percent. The direction of the principal strains is indicated with exceptional precision. When checks with other gages are desired, the qualitative picture of areas and directions of principal strains provides an excellent aid in placing the gages.

Painting of Brittle Lacquers

All the apparatus essential for this type of strain analysis are grouped in the cabinet in Fig. 1. Spray-gun, air regulator, and calibrator are on the upper shelf; psychrometer, calibration strips, and their scale are in the drawer; lacquers are in the bottom tray, and lacquer selection chart and psychrometer chart are on the door.

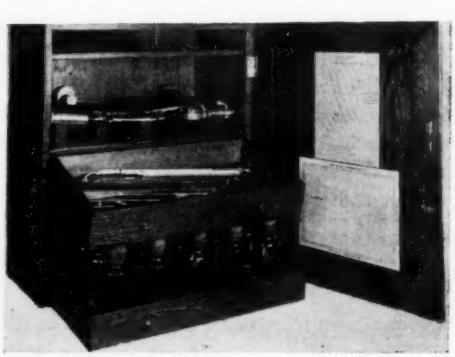

Fig. 1. Apparatus for brittle lacquer strain analysis.

The brittle lacquers are best applied with a spray-gun. Surprisingly, clouds of bubbles driven into the lacquer coating by the action of the gun not only cause no detrimental effect on the brittle properties of the coating, but aid materially in causing more uniform cracking.

A bright surface beneath the brittle coating is essential for cracks to be visible. If the surface is not naturally reflecting, a specially prepared aluminum-pigmented undercoating lacquer is used. This provides a good reflecting surface and will dry sufficiently in thirty minutes to allow painting of the brittle lacquer.

Illustrations of the Use of Brittle Coatings

Fig. 3 shows four stages during the loading in tension of a plate with a somewhat elliptical hole. From the load and local strain data, the concentration factor of the hole is easily computed.

A brass bar twisted in torsion shows, in Fig. 4, the principal tension strains as continuous cracks formed during loading. In addition, the compression strains are shown by short cracks interspersed between the tension cracks and at right angles to them. These compression cracks were formed by the relaxation of the load after it had been held at its maximum value for an hour.

Fig. 5 illustrates the different straining of two welds of identical size and loading, but with one preformed so that the line of action of the two plates is a single straight line, while the other has eccentric lines of action. The eccentricity introduces bending into the welded joint on the right, materially increasing the amount of strain in the plate next the weld. The preformed lap joint has much less strain which is distributed up onto the weld, instead of being confined to the plate at the weld junction.

Plain and corrugated sections of 0.050 dural sheet with holes in the center and loaded vertically in compression are shown in Fig. 6. The elastic buckling of each plate produced the strain patterns seen. The nature of the buckling can be easily reconstructed from the tension strain patterns left in the brittle coatings on the sheets.

The unusual pattern in Fig. 7 is caused by plastic flow lines, often called "Luder's lines," propagating from a Brinell impression in soft steel. They radiate at about 45° to the circular elastic strain patterns, showing that they are connected with the maximum shear stresses.

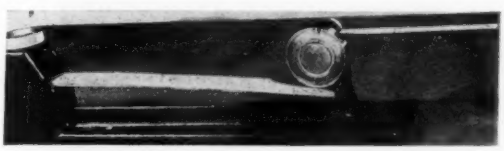

Fig. 2. Calibration strip under load in the calibrator.

Fig. 4. Round bar in torsion. Long cracks show tension strain; short cracks, compression.

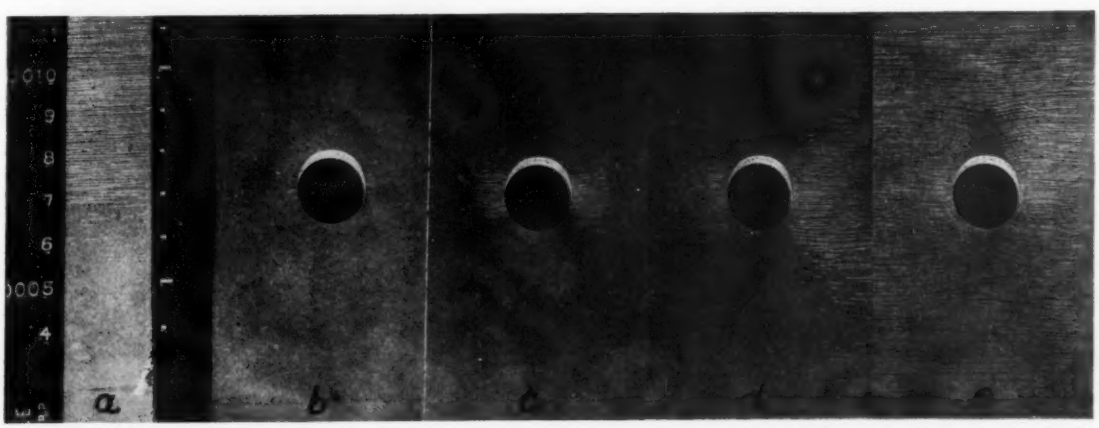

Fig. 3. (a) Calibration strip in scale which is marked in inches per inch strain. (b) Plate with hole; 5000 lb. load. (c) Plate with hole; 9000 lb. load. (d) Plate with hole; 14,000 lb. load. (e) Plate with hole; 17,000 lb. load. Concentration factor = load at e/load at b = 3.4.

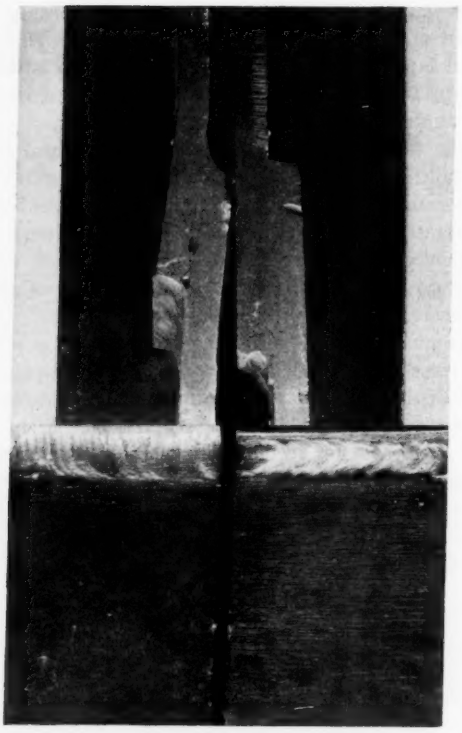

FIG. 5. Lap welds in tension; same size, same load. (a) Formed to single line of action. (b) Straight lap with usual eccentric lines of action.

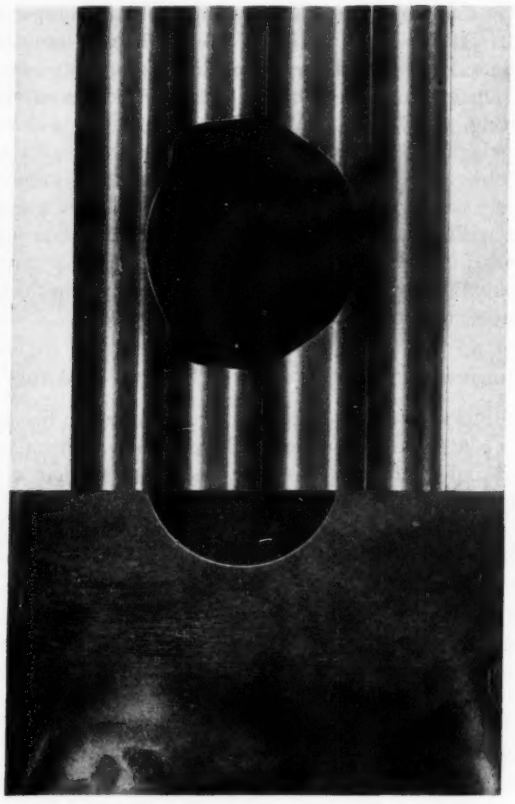

FIG. 6. Elastic buckling of plain and corrugated aluminum sheet; vertical compressive loading.

Although many other examples could be given, these few should indicate the diversity of strain distribution problems in which brittle lacquers may be of aid.

FIG. 7. "Luder's" plastic flow lines around a Brinell impression in soft steel

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Two Formulas for Take-Off Distance

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ABSTRACT

Two formulas for take-off distance are developed. The first formula takes into account all the important factors affecting take-off distance, and may usually be trusted to give results in error by no more than 2 percent. The second formula is a simplification of the first, and will usually give results accurate to within 5 percent. Both formulas permit comparatively rapid solutions.

INTRODUCTION

IN THE following development of two analytic expressions for take-off run, it is assumed that sea level conditions exist and that there is no wind. Other conditions can be dealt with by similar procedure. During the take-off run the airplane is assumed to be held in such an attitude that the air resistance plus ground resistance is a minimum. This attitude is assumed to be maintained until the velocity becomes that required to take off at the given lift coefficient C_{L_t}.

The formulas developed provide simple analytic expressions for the take-off distance that would be secured by using the procedure outlined by Hartman.[1]

NOTATION

s = Take-off distance in ft.
μ = Coefficient of ground friction.
W = Gross weight of airplane in lbs.
A = Effective aspect ratio including ground effect.
b_e = Effective span including ground effect.
f = Equivalent parasite area, defined by:

$$\text{Parasite drag} = {}^1/_2\rho V^2 f.$$

a = Acceleration of the airplane in ft. per sec.^{2}
C_{L_t} = Given take-off lift coefficient.
V_t = Velocity for take-off at $C_L = C_{L_t}$, ft. per sec.
$V_1 = \sqrt{1/_2}\, V_t$, ft. per sec.
V_m = High speed at sea level, ft. per sec. or m.p.h.
t.hp. = Thrust horsepower available.
t.hp.$_m$ = Maximum thrust horsepower available.
S = Wing area, sq. ft.
$L_p = W/f$, Oswald's parasite loading.[2]
$L_s = W/b_e^2$, Oswald's span loading modified to include ground effect.
$L = W/\text{t.hp.}_m$ = Oswald's power loading.
$L_w = W/S$, wing loading, lbs. per sq.ft.
R = Ground plus air resistance during take-off.
R_1 = Ground plus air resistance at $V = V_1$.
g = Acceleration of gravity = 32.174 ft. per sec.^{2}

$$m = \frac{\text{t.hp.}/\text{t.hp.}_m}{V/V_m}$$

m_1 = m at $V = V_1$.
T = Propeller thrust.
T_1 = Propeller thrust at $V = V_1$.

DERIVATION OF THE FORMULAS

It has been pointed out by Hartman[1] that if, during the take-off run, ${}^1/_2a$ plots as a straight line against V^2, the take-off distance is given exactly by

$$s = V_t^2/2a_1 \tag{1}$$

Here a_1 is the acceleration at $V = V_1 = \sqrt{1/_2}V_t$. Since for any airplane ${}^1/_2a$ plots very nearly as a straight line against V^2, the take-off formulas developed will be Eq. (1) with a_1 expressed in terms of known design data.

Hartman has shown that for take-off at the assumed attitude giving minimum total resistance, the lift coefficient is

$$C_L = {}^1/_2\pi A\mu \tag{2}$$

At this lift coefficient Hartman has shown that ground plus air resistance is:

$$R = W\mu + \rho f V^2/2 - \pi\rho\mu^2 b_e^2 V^2/8 \tag{3}$$

This is to be evaluated at $V = V_1 = \sqrt{1/_2}V_t$. Putting the relations $\rho V_1^2/2 = L_w/2C_{L_t}$, L_p and L_s in Eq. (3) and dividing by W,

$$\frac{R_1}{W} = \mu + \frac{L_w}{2C_{L_t}L_p} - \frac{\pi\mu^2 L_w}{8C_{L_t}L_s} \tag{4}$$

The thrust divided by the gross weight is

$$T/W = 550\text{t.hp.}/VW \tag{5}$$

Introducing m, which characterizes the engine-propeller combination, and L_t in Eq. (5),

$$T/W = 550m/V_m L_t \tag{6}$$

The factor 550 becomes 375 if V_m is expressed, as it usually is, in m.p.h. If V_m is in m.p.h., Eq. (6) evaluated for $V = V_1$ becomes

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$$T_1/W = 375m_1/V_mL_t \tag{7}$$

The acceleration at $V = V_1$ is then

$$a_1 = g[(T_1 - R_1)/W] \tag{8}$$

Eqs. (4) and (7) are now put in Eq. (8). The resulting expression for a_1 is then put in Eq. (1). Since at sea level,

$$V_t^2 = \frac{2L_w}{\rho_0 C_{L_t}} = \frac{841L_w}{C_{L_t}} \tag{9}$$

Eq. (1) becomes

$$\frac{1}{s} = \frac{32.174 \times 2C_{L_t}}{841L_w}\left[\frac{375m_1}{V_mL_t} - \mu - \frac{L_w}{2C_{L_t}L_p} + \frac{.393\mu^2L_w}{C_{L_t}L_s}\right] \tag{10}$$

This reduces to:

$$\frac{1}{s} = \frac{1}{L_w}\left[\frac{28.69m_1C_{L_t}}{V_mL_t} - .0765C_{L_t}\mu\right] - \frac{.0383}{L_p} + \frac{.0300\mu^2}{L_s} \tag{11}$$

Eq. (11) is the first formula for take-off distance. It has been found to give in most cases results which agree within 1 percent or 2 percent with the theoretically exact values obtained from

$$s = \int_0^{V_t} \frac{VdV}{a} = \int_0^{V_t^2} \frac{d(V^2)}{2a} \tag{12}$$

It has been found that in all cases the last two terms in Eq. (11) are small in comparison with the other two terms on the right side. The contribution to $1/s$ of these last two terms is of the order of minus 5 percent of $1/s$. Hence an approximate formula can be obtained by neglecting these two terms and changing the constants. This procedure gives

$$s = \frac{L_w}{C_{L_t}[(27m_1/V_mL_t) - .072\mu]} \tag{13}$$

Note that in Eqs. (11) and (13) V_m is in m.p.h.

Determination of m

In order to determine m, the variation of t.hp. with velocity at full throttle must be known for the particular engine-propeller combination used. From the non-dimensional plot of t.hp./t.hp.$_m$ against V/V_m a curve of m against V/V_m can be plotted. This has been done for the general thrust horsepower curves given by Hartman.[1] The results are given in Fig. 1. In this figure points on the m curves were obtained by a simple geometrical construction illustrated by the dotted lines for $V/V_m = .45$. The vertical reference line is located at $V/V_m = .25$ as .25 is the ratio of the left scale to the right scale. Having the m curve, m_1 is then obtained as the value of m for $V = V_1$. V_1 has the value

$$V_1 = 20.50\sqrt{\frac{L_w}{C_{L_t}}} \text{ ft. per sec.} = 13.98\sqrt{\frac{L_w}{C_{L_t}}} \text{ m.p.h.} \tag{14}$$

Determination of the Effective Span

The effective span b_e used in the above derivations includes ground effect and hence differs from Oswald's effective span. An effective span including ground effects accurate enough for most purposes can be obtained by dividing Oswald's effective span $\sqrt{e} \times kb$ by the factor:

$$\sqrt{\frac{\text{Induced drag during ground run}}{\text{Induced drag in normal flight}}}$$

This factor may be determined from a chart given by Warner.[3] It has been found by an examination of several examples that a neglect of the ground effect leads to a take-off distance which is of the order 5 percent too high.

Accuracy of the Formulas

The take-off distance for three airplanes was computed by the theoretically exact method (Eq. (12)) and by Eqs. (11) and (13). The data used and the final results are given in Table 1. In Example 1 a constant speed propeller is assumed and the t.hp. variation is assumed to be that given by the upper curves of Fig. 1. In Example 2 a fixed pitch propeller having the t.hp. variation given by the lower curves of Fig. 1 is assumed. In Example 3 a fixed pitch propeller is assumed, the blade angle β being 22° and Diehl's power drop factor[4] being .80. The charac-

Table 1

Example	1	2	3
C_{L_t}	1.40	1.35	1.35
μ	.03	.08	.05
W, lbs.	8650	5000	1058
b_e, ft.	49.5	44.8	30.7
t.hp.$_m$	680	415	30
f, sq.ft.	8.4	19.2	4.7
S, sq.ft.	352	400	149
V_m, m.p.h.	225	142	93
L_s	3.53	2.49	.893
L_t	12.70	12.05	35.20
L_p	1028	260	225
L_w	24.6	12.5	7.1
V_t, ft. per sec.	121.5	88.2	47.1
s, exact, ft.	1032	500	618
s, Eq. (11), ft.	1034	503	615
s, Eq. (13), ft.	1063	516	620

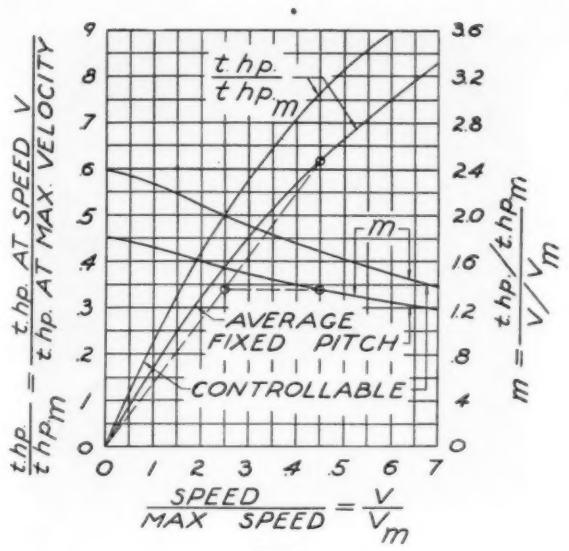

FIG. 1.

teristics of this combination are given by Diehl.

It is seen that Eq. (11) gives results which are within .6 percent of the exact results for the three examples. The greatest error incurred by using Eq. (13) was 2.8 percent, and all errors made by using this formula were conservative.

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Letter to the Editor

February 16, 1940

Dear Sir:

The construction and characteristics of the Telegon System as developed by the Kollsman Instrument Division of the Square D Company are described below. Several uses, including that in connection with the equipment described in the paper entitled *Flightray, a Multiple Instrument Indicator* by Bassett and Lyman, appearing in this issue of the Journal of the Aeronautical Sciences, are indicated.

Self-synchronous motors have long been used in the electrical industry for duplicating motion at some point distant from its source. When two such motors are connected and energized by proper source of alternating current, their rotors will always remain in exactly the same angular position with respect to their stators. Thus, if the rotor of one motor is moved by an outside force, the rotor of the other will follow automatically.

Basically, this is the principle of operation of Telegon. However, the Telegon unit is designed especially for aircraft instrument use and consequently is radically different in construction from all other self-synchronous motors.

In order to reduce the weight of the rotor, the primary coil is separated from the rotating element as shown in Fig. 1. A hollow soft iron shaft carrying two vanes is mounted on steel pivots and because of its extremely light weight is supported by jewel bearings. By separating the energizing coil from the rotor, objectionable brushes or slip rings are eliminated. Not only does this remove practically all friction, but brings with it the explosion-proof qualities required by certain operations. Due to the complete absence of electrical transients, radio interference is eliminated.

The secondary circuit employs two phase windings disposed at right angles to each other as shown in Fig. 1.

Fig. 2 shows a wiring diagram for two units; in this instance one unit would be coupled to a transmitting instrument while the other would be equipped with a pointer and dial.

When the primary coil is energized a magnetic flux is induced in the center of the rotor *K* and transmitted to the vanes, the

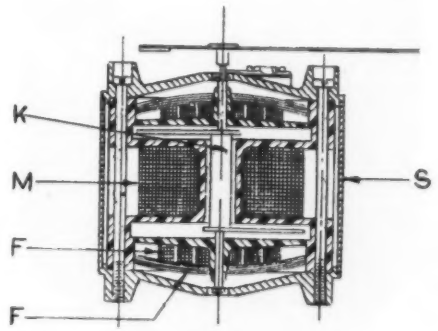

FIG. 1.

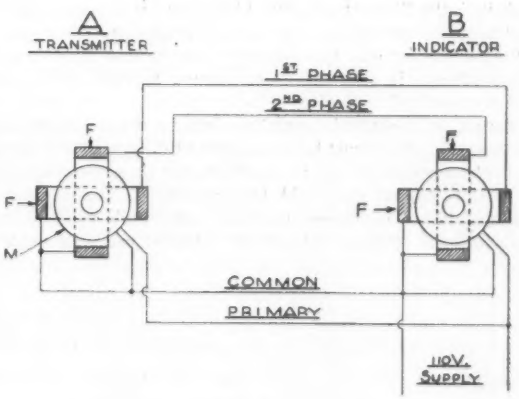

FIG. 2.

magnetic circuit being completed by a soft iron cylindrical outer shell. This shell also serves as a magnetic shield preventing interaction between units when grouped in multiple indicators.

As the shaft assembly of the transmitting unit is rotated, the corresponding induced magnetic field is also rotated. This field pattern induces an E.M.F. in the phase windings (F-F') the voltage in each phase being determined by the geometric alignment of the rotor to the phase windings. The voltages thus induced give rise to proportional currents which flow in the phase windings of both the transmitting and the indicating units, setting up a flux pattern in the indicating unit identical to the pattern in the transmitting unit. This flux in the indicating unit reacts with the vanes (which are magnetized from the same source as the transmitting unit) causing the rotor to assume the same angular position as that of the transmitting unit.

Each Telegon motor draws 1.25 watts operating on single phase alternating current of from 24 to 120 volts and at any frequency between 300 and 800 cycles. The power factor averages 40 percent and the temperature rise for continuous operation is 28°C.

Telegon units (Fig. 3) weigh 4 ounces each, are $1^1/_2$ inches long and $1^1/_2$ inches in diameter. Because of their small size they may be grouped in multiple scale indicators. The four

FIG. 4.

FIG. 3.

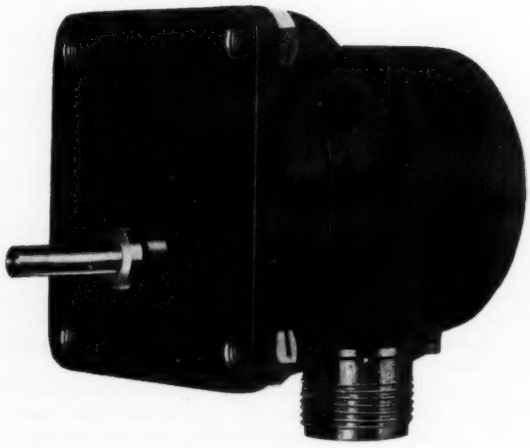

FIG. 5. A geared position transmitter.

scale indicator illustrated in Fig. 4 occupies a board area equal to that normally allotted to one standard indicator. Two motors arranged side by side in a standard case geared to concentric handstaffs may be used where two pointers moving over a single dial are required.

Torque, in measurable quantities, is not a feature of the Telegon motors. They must be compatible with the standard instruments from which no power is available and their operation must be possible without appreciable loss in accuracy. One transmitter can operate two indicators, and the torque, while small, is more than sufficient to move the pointer. This is considered ample.

While the Telegon system is normally applied to the remote indication of instrument readings and position indication, single Telegon motors are used by the Sperry Gyroscope Company in connection with their Flightray development. A modified Telegon motor also serves as a synchroscope when used in conjunction with Electric Tachometers. In this instance the primary circuit is connected to one tachometer generator and the phase windings to the other. The rotor will then act as a beat frequency indicator being stationary when a condition of synchronization is reached and at other times rotating at a speed proportional to the difference in engine speeds.

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Effective Widths in Stiffened Panels under Compression

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ABSTRACT

A general equation is obtained for the effective width of flat sheet in semi-monocoque structures. This equation is similar to that given by von Kármán,[1] differing only in the magnitude of the buckling constant.

The effects of a decreasing modulus of elasticity at high stresses, inter-rivet buckling, and differences in strength between the stiffener material and the sheet material are taken into account. Curves of effective width of sheet *versus* stiffener stress are plotted to enable the designer to apply the theory readily to the design of structures.

The close agreement between the theory and test data substantiates the several assumptions made in developing the formulae.

INTRODUCTION

THE compressive strength of flat sheet in monocoque and semi-monocoque construction has been treated by a number of investigators. von Kármán proposed the original theory which has since been modified and expanded by others. This theory was based on the assumption that the edge or boundary conditions in the sheet at the sides represented a simply supported edge. From this, a formula was developed for an effective width of sheet which was assumed to be acting with each stiffener at the stiffener stress in semi-monocoque structures.

Sechler[2] obtained some empirical constants to be used with the general theory, but the agreement between this theory and experimental test data is not good in all cases. Marguerre[3] also obtained some empirical constants, but again the agreement with test data is poor. The purpose of this paper is to revise and expand the general theory to account for certain factors observed in stiffened panel tests which were previously neglected in the determination of the effective width formulae.

Symbols

t = Sheet thickness (inches).
b_e = Total effective width of sheet acting with each stiffener (inches).
b = Stiffener spacing (inches).
f_{cr} = Initial buckling stress of sheet in stiffened panels (lbs. per sq.in.).
f_{st} = Stiffener stress (lbs. per sq.in.).
f_{sh} = Sheet stress (lbs. per sq.in.).
f_e = Stiffener stress at which inter-rivet buckling occurs (lbs. per sq.in.).
s = Rivet spacing (inches).
E = Modulus of elasticity of stiffener (lbs. per sq.in.).

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GENERAL THEORY

An examination of the behavior of the sheet in a stiffened panel under a compressive stress greatly exceeding the initial buckling stress of the sheet reveals that the assumption of a simply supported edge at the stiffener attachment is not strictly correct. Fig. 1 shows a cross-section of a stiffened panel compressed axially with the buckled sheet represented by the heavy line and the original position of the unbuckled sheet represented by the dotted line. At the line of attachment of the sheet to the stiffener the sheet will take the slope of the leg of the stiffener. If the stiffener remains in its original position, the boundary conditions in the sheet at the stiffener will simulate those of a clamped edge providing the sheet is continuous over a number of stiffeners as in semi-monocoque construction. However, if the sheet gage is heavy, the twisting moment induced into the stiffener by the buckled sheet will tend to rotate the stiffener in the direction shown by the arrows in Fig. 1 and thus change the boundary conditions. But the waves in the sheet in a direction parallel to the stiffeners will approximate a sine wave with the half-wave length nearly equal to the stiffener spacing. That is, approximately square half-waves will be formed with the half-waves being slightly shorter than they are wide, due to the clamping action of the attachment along the stiffeners. Thus a twisting moment over only half a wave length will be induced in the stiffener in one direction and an equal moment will be induced in the stiffener in the opposite direction over the other half of the wave. Consequently these moments will tend to compensate each other over a long panel

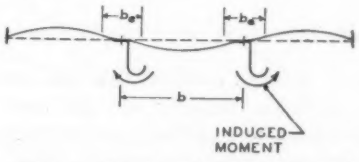

FIG. 1. Cross section of sheet and stiffener combination loaded axially in compression.

length and so, for most cases met in aircraft design, this twisting may be neglected. Hence, the condition of a clamped edge may generally be assumed to be valid for semi-monocoque construction. Exceptions to this will be discussed later.

The following equation for the buckling of flat sheet under edge compression is obtained from Timoshenko:[4]

$$f_{cr} = k\pi^2 E t^2/12(1 - u^2)b^2 \qquad (1)$$

where Poisson's ratio, u, is 0.3 for dural and the minimum value of k for a clamped edge is given as 6.97.

Hence,

$$f_{cr} = 6.32Et^2/b^2 \qquad (2)$$

By substituting b_e for b in the above formula and assuming the stress in the sheet adjacent to the stiffener to be acting at the stiffener stress, f_{st},

$$b_e = 2.52t\sqrt{E/f_{st}} \qquad (3)$$

This represents the effective width of flat sheet acting at any particular stiffener stress at or above the initial buckling stress. It may be seen that this formula is similar to the von Kármán formula except for the difference in the buckling constant.

Effect of Variation in Modulus of Elasticity

The above formula assumes that the same material is used in both the stiffener and the sheet and that the compressive stress of the material does not exceed the proportional limit. However, such conditions are not always met in aircraft design, hence, it is necessary to consider these variables.

The modulus of elasticity of the aluminum alloys begins to decrease from a value of about 10^7 after the proportional limit is reached. Howland[5] has shown this variation of the modulus with stress as the ratio de/df_{sh} known as the tangent modulus and has plotted average curves of E against tensile stress for several materials. This tangent modulus should be used in the effective width equation rather than the constant modulus. Sufficient proof of the tangent modulus is still lacking, but it is undoubtedly a fair approximation of actual conditions. It should be noted that since stiffener stress is used in the formula, the modulus of the stiffener at the particular stress and not the modulus of the sheet should be used in determining the effective width.

Differences between the strength of the sheet material and stiffener material must be compensated for in the formula. Since stiffener stress is of primary concern, it is necessary to express the effective width formula in terms of stiffener stress and correct for the different strength of the sheet.

Sechler[2] has shown by strain measurements on a panel that at the higher stresses most of the load in the sheet is carried by that portion adjacent to the stiffener. By assuming all the stress is carried by a rectangular sheet adjacent to the stiffener equal in width to b_{e_1} and acting at the stiffener stress, the load in the sheet will be $b_{e_1} \times t \times f_{sh}$ where f_{sh} is the sheet stress corresponding to the stiffener stress at the same unit strain (points A and B in Fig. 2) and b_{e_1} is the uncorrected effective width corresponding to the stiffener stress. Expressing this load in terms of

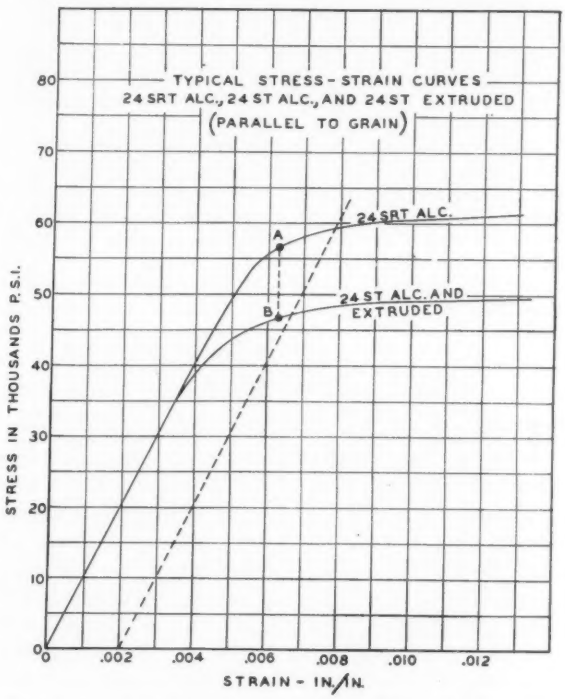

Fig. 2. Typical stress-strain curves for 24ST Alclad, 24ST extruded dural, and 24SRT Alclad.

stiffener stress and the correct effective width (b_e) acting at the stiffener stress, the following equation is obtained.

$$P = f_{sh} \times t \times b_{e_1} = f_{st} \times t \times b_e \qquad (4)$$

or,

$$b_e = \frac{f_{sh}}{f_{st}} b_{e_1} = 2.52\, t \frac{f_{sh}}{f_{st}} \sqrt{\frac{E}{f_{st}}} \qquad (5)$$

It may be seen that when the stress-strain curves of the two materials coincide, the value of f_{sh}/f_{st} will be unity and the original equation will be obtained. The above equation may be used for a combination of SRT stiffeners and ST sheet or any other combination of materials whose stress-strain curves are known.

Effect of Inter-Rivet Buckling

The strength of the sheet after inter-rivet buckling occurs may be treated in a manner similar to that for dissimilar materials and the same assumptions used. Inter-rivet buckling is a column failure of the sheet between rivets and since the total load in the sheet is

assumed to be carried by an effective width at the stiffener, this effective width may be regarded as representing the column between rivets. When a column of any type is loaded axially in compression, it will sustain its maximum stress over a relatively large deflection before any large decrease is detected. Thus, it may safely be assumed that after inter-rivet buckling occurs, the sheet stress at which it occurs will remain practically constant till the failure stress of the stiffener is reached. Then, proceeding as before, the effective width of the sheet at stiffener stresses above the inter-rivet buckling stress will be represented by

$$b_e = 2.52t\frac{f_e}{f_{st}}\sqrt{\frac{E}{f_{st}}} \tag{6}$$

Combining this equation with the equation for dissimilar materials,

$$b_e = 2.52t\frac{f_e f_{sh}}{f_{st}^2}\sqrt{\frac{E}{f_{st}}} \tag{7}$$

The inter-rivet buckling stress, f_e, was originally determined by Howland[6] and corrected by Newell.[7] However, the corrected curves given by Newell do not cover the range of stresses above 44,000 lbs. per sq.in., hence, in Fig. 3 curves for inter-rivet buckling stress are given to cover the entire range of stresses covered by the curves in Fig. 2. The curves in Fig. 2 were selected as representing typical stress-strain curves for 24ST alclad, 24SRT alclad, and 24ST extruded dural as indicated. Instead of using the Johnson parabolic curves for short columns above a stress of 20,000 lbs. per sq.in. as suggested by Newell, the Euler formula with a tangent modulus taken from the curves in Fig. 2 is used to determine the inter-rivet buckling stress. Two curves are given in Fig. 3, one for 24SRT alclad stiffeners and the other for 24ST alclad and extruded stiffeners. The inter-rivet buckling stress must be taken from the curve corresponding to the stiffener material used and not the sheet material.

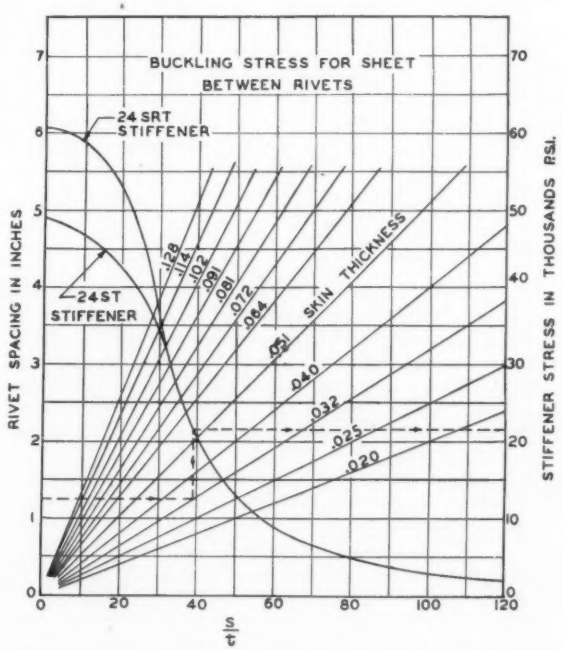

FIG. 3. Inter-rivet buckling curves for flat sheet attached to 24ST and 24SRT stiffeners.

It must be remembered that this formula applies only when the stiffener stress is above the inter-rivet buckling stress. When the inter-rivet buckling stress is above the stiffener stress, the value of f_e/f_{st} becomes unity.

APPLICATION OF THEORY TO DESIGN

In Fig. 4 are plotted curves of effective width of sheet against stiffener stress for various standard gages of 24ST alclad sheet commonly used in aircraft design. The curves are plotted for $s = 0$ or continuous

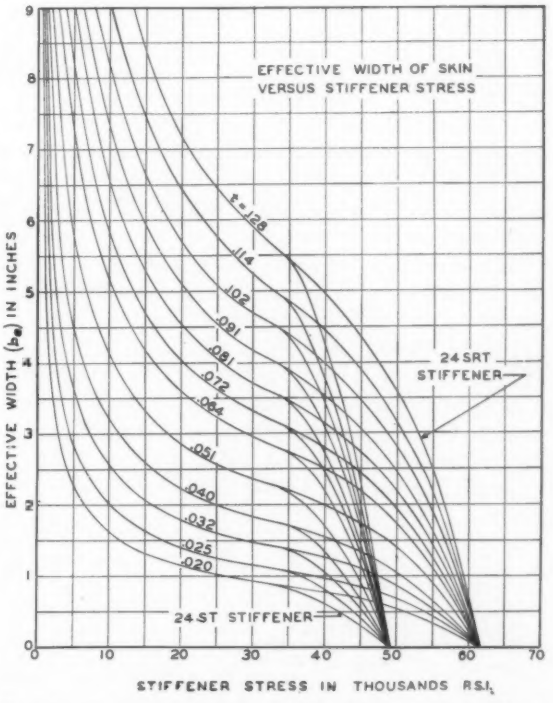

FIG. 4. Curves of effective width of skin *versus* stiffener stress for various standard sheet gages of 24ST Alclad.

attachment of sheet to stiffener and for two stiffener materials, 24ST alclad and 24SRT alclad, whose stress-strain curves are shown in Fig. 2. It may also be assumed without serious error that extruded 24ST dural has the same properties as 24ST alclad, hence, the 24ST alclad curves may be used for this material. It should be obvious that the limiting value of b_e in the curves of Fig. 4 is the stiffener spacing.

To use the curves for any rivet spacing above $s = 0$,

determine the inter-rivet buckling stress, f_e, from Fig. 3 for the proper stiffener material. If this is below the design stiffener stress, f_{st}, determine the ratio f_e/f_{st} and multiply this by the effective width determined from Fig. 4 for $s = 0$. For any other combination of sheet and stiffener materials, the effective width must be determined from Eq. (7).

The agreement of test data with the general theory is shown in Fig. 5. The test points given in Table 2

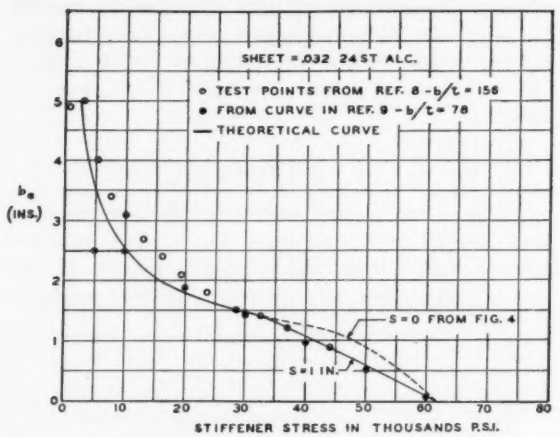
SHEET = .032 24ST ALC.
○ TEST POINTS FROM REF. 8 - b/t = 156
● FROM CURVE IN REF. 9 - b/t = 78
— THEORETICAL CURVE
b_e (INS.)
S = 0 FROM FIG. 4
S = 1 IN.
STIFFENER STRESS IN THOUSANDS P.S.I.

FIG. 5. Comparison of test data with general theory.

of reference 8 are compared with the theoretical curve for 0.032 sheet. The rivet spacing on the test panel was one inch for which, from Fig. 3, the inter-rivet buckling stress is 34,000 lbs. per sq.in. The theoretical curve is corrected for inter-rivet buckling and shows good agreement with the test data especially at the high stresses where the experimental method of determining the effective width was most accurate. Points taken from Fig. 4 of reference 9 for 0.032 sheet attached to corrugations are also compared with the theoretical curve and again good agreement is obtained.

As previously mentioned there are exceptions to the general theory. It has been found from an examination of available test data on stiffened test panels that for values of b/t less than 75 the moments induced into the stiffeners by the sheet become of sufficient magnitude to alter the boundary conditions. This variation of effective width with b/t is mentioned in reference 8 and is due to a decreasing stiffener spacing or an increasing sheet gage causing an increase in the moments induced into the stiffener. A reduction factor of 0.76 for sheet—stiffener combinations with a b/t below 75 gives a more nearly correct effective width, that is, the effective width determined by Eq. (7) or from Fig. 4 should be reduced 24 percent. This reduction corresponds to an effective width for a simply supported edge.

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Book Review

Illyne's Star Chart, by ALEXIS ILLYNE, Weems System of Navigation, 1939; 22 pages, $1.00.

The Star Chart is a 31 × 31 inch, accurately engraved diagram of the heavens and is beautifully constructed for the utmost utility. Briefly, it is projected with the right ascension and declination coordinates (heavenly latitude and longitude) with 60° of our northern hemisphere in the center circular projection. From this in four rectangular projections are the seasonal stars.

This particular arrangement and use of two projections were arrived at by the author to provide a chart of accuracy and minimum distortion. The stars will appear in the heavens as they do on the chart; first, in the circular projection as the observer looks toward the North Star, secondly, in each of the four rectangular projections as he looks south in fall, winter, spring or summer (assuming his zenith is somewhere near the mid latitude of the U.S.).

In the corners of the chart are added larger scale photographic appearances of the principal constellations of the four seasons and the southern polar heavens, making the chart complete.

Built around this chart is a concise booklet of some 22 pages explaining its use and containing helpful clear-cut information concerning the hourly position of the stars. A section is devoted to the planets and contains data on their size, position, appearance, and movement.

Appendices include lists of navigational stars, first and second magnitude stars, double and variable stars.

On the whole, the booklet and chart are presented both to the amateur with no previous knowledge of astronomy and to the celestial navigator as a "road map" of the heavens. With the guidance of such a booklet, to quote the author, "The location of definite stars on this Chart soon becomes as familiar as such points as New York and Chicago on an ordinary map."

T. C. GILLMER
U.S. Naval Reserve

Institute Notes

New Address of the Institute

The Institute has moved from its offices at 5111 RCA Building to 1505 RCA Building West, Rockefeller Center, New York. This is the new address of both the Institute and the Aeronautical Archives.

Gifts to the Aeronautical Archives

The announcement, at the Honors Night and Annual Dinner, that the Institute had established an Aeronautical Archives, has met with a remarkable response in the form of gifts. They are so numerous that it is difficult in the space available in the Journal to give in detail an itemized list. Later it is hoped a more complete record may be given. The gifts received will be acknowledged in the order of their receipt, rather than in the order of their value or importance.

Frank A. Tichenor presented over one hundred bound volumes of the *Congressional Record* containing many speeches and reports on aviation.

Frank T. Coffyn gave a rare collection of clippings, photographs, and manuscripts pertaining to the early days of flying in this country. He was one of the first six pilots trained by the Wright Brothers and flew three thousand hours in early Wright airplanes. Some of the photographs and manuscripts are unique, and they will add greatly to the historical value of the Archives.

Jerome Lederer gave a collection of pamphlets on Meteorology and a dozen *N.A.C.A. Annual Reports.*

Funk and Wagnalls Company gave the following books: *This Flying Game* by H. H. Arnold and Ira C. Eaker (1938); *Through the Overcast,* and *Your Wings* by Assen Jordanoff (1939).

The Stevens Institute of Technology presented Technical Memorandums Nos. 41, 42, 44, and 45, dealing with investigations in the Stevens Experimental Towing Tank, and Report No. 100, which is the annual report on the towing tank for the year 1939.

John Wiley and Sons gave the following books: *The A B C of Flight* by W. Laurence LePage (1928); *Elements of Practical Aerodynamics* by Bradley Jones (1939); *Principles and Problems of Aircraft Engines* by Minor M. Farleigh (1931); *Dynamics of Airplanes and Airplane Structures* by John E. Younger and Baldwin M. Woods (1931); *Applied Aerial Photography* by Ashley C. McKinley (1929).

Reinhold Publishing Corporation gave the following books: *Aluminum Paint and Powder* by Junius David Edwards (1936); *A Survey of Nitrocellulose Lacquer* by Bruce K. Brown and Francis M. Crawford (1928); *Corrosion Resistance of Metals and Alloys* by Robert J. McKay and Robert Worthington (1937); *The Chemistry of Synthetic Surface Coatings* by William Krumbhaar.

Harcourt, Brace and Company gave a copy of *North to the Orient* by Anne Morrow Lindbergh (1935).

Aeronautics Education Foundation gave the following books: *Aviation, or Human Flight through the Ages* by Ernest E. Walker (1939); *Aviación, o el Vuelo Humano a Través de los Siglos* by Ernest E. Walker (1939).

The American Institute of Physics donated a cumulative index of the Journal of the Acoustical Society of America.

Denis Mulligan gave a copy of his recently published survey of aircraft manufacture in Chicago.

Harry P. Christofferson sent a collection of rare photographs, some of them being pictures of the flying boats used on the first regular airline in the United States, which he and his brother started, between Oakland, California, and San Francisco. Each photograph has been carefully captioned, and will be a valuable addition to the historical records of the Archives.

The National Advisory Committee for Aeronautics has sent several hundred copies of Technical Notes and Memoranda to assist the Archives to complete their files of these indispensable reference reports.

F. W. Locke, Jr., presented a collection of magazines and airplane catalogs.

Lester D. Gardner gave a collection of twenty medallions which will form the nucleus of the Archives medallion exhibit.

A. P. Loening added to this exhibit with the gift of four valuable early French medallions. Mr. Loening's gift also included forty books.

Mrs. Bella C. Landauer presented a large and rare engraving, colored by hand, showing the various types of early balloons and some of the early attempts to construct dirigibles.

Hart O. Berg, of Paris, who represented the Wright Brothers in Europe for several years, supplemented his earlier gifts of clippings dealing with the early days of flying, with many photographs of the Wright Brothers in Europe and a most remarkable collection of documents relating to the Wright Brothers negotiations in Europe.

Thomas H. Beck sent a two-volume *New Standard Dictionary.* He also had made a set of photostats of early articles on flying from *Collier's Magazine.*

Grover Loening sent a collection of about seventy-five books. In his letter accompanying the gift Mr. Loening expressed so well the helpful attitude of donors to the Archives, that excerpts from it are reprinted here with the hope that others may feel disposed to follow his example:

"Since I began my study of aviation in 1909, over thirty years ago, I have amassed a considerable collection of books, photographs, documents, medallions, and newspaper clippings, all of which I desire to contribute to the Aeronautical Archives. The seventy-five books that I am sending to you today will merely be a beginning, as it will take me some time to go through the remainder of the large amount of material that I have.

"I have sent under separate cover by registered mail, four books that I consider of especial value as a gift to the Archives. One is a copy of the original publication of *Progress in Flying Machines* by O. Chanute; another is one of the original copies of *Some Aeronautical Experiments* by Wilbur Wright, which was the first technical publication of the Wright Brothers; another is an early and valuable book on *Aeroplane Patents* by R. M. Neilson; and the fourth is a copy of Mouillard's work on Soaring."

Personnel Opportunities

The Personnel Bureau serves individual members, as well as organizations seeking to employ aeronautical specialists. Any member or organization may have requirements listed without charge.

Wanted

A midwestern aircraft manufacturer has openings for a number of aeronautical engineers having from five to eight years' experience. They should be capable of assuming responsible positions, such as Project Engineers, and should have previous experience at least on detail design and as Assistant Project Engineers. Address reply to Box 98, Institute of the Aeronautical Sciences.

Eleventh Annual Safety Convention

The Eleventh Annual Safety Convention, under the auspices of the Greater New York Safety Council, will be held in New York at the Pennsylvania Hotel on April 16, 17, and 18, 1940. The aviation meetings will be held on Wednesday, April 17th. Members of the Institute as well as the general public are invited to attend. Following is the preliminary program of the aviation sessions.

Wednesday, April 17

9:30 a.m. **Private Flying Session**

Chairmen: GILL ROBB WILSON, President, N.A.A.
R. W. SCHROEDER, United Air Lines Transport Corporation

GROVE WEBSTER, Civil Aeronautics Authority, **Safety Factors Applied to Our National Private Flying Program.**
Non-Airline Traffic Control (group discussion).

2:00 p.m. **Transport Session**

Chairmen: C. R. SMITH, American Airlines.
R. W. SCHROEDER, United Air Lines Transport Corporation

THEODORE P. WRIGHT, Curtiss-Wright Corporation, **Aviation Today and Tomorrow.**

S. PAUL JOHNSTON, National Advisory Committee for Aeronautics, **Recent Developments in Research as Factors in Increased Safety in Flight.**

Branches

Seattle. At a meeting of the Branch on January 24th, Mr. Thiele of Pan American Airways presented the film, "Flying the Pacific," and Messrs. Harvill and Boothe of the Harvill Aircraft Die Casting Corporation presented the film, "Die Casting the Modern Way." One hundred and seventy-four members of the Branch and 69 guests attended. Both films were found to be of great interest.

Los Angeles. At a dinner meeting on February 23rd, Irving R. Metcalf of the Civil Aeronautics Authority discussed "Some Solutions to the Blind Landing Problem." Mr. Metcalf also discussed the research programs now in progress under the auspices of the Civil Aeronautics Authority. An interesting discussion followed the presentation.

Student Branches

Carnegie Institute of Technology. Meetings of the Student Branch were held on December 8th and February 11th. At the first, Robert Owen presented the Branch Lecture on "Aviation Fuels" by Dr. Graham Edgar. At the second, Marion Hockman gave the Branch Lecture, "Safety from the Ground Up," by Jerome Lederer. Following this the motion picture, "Safe Flying," which deals with the activities of the N.A.C.A. was shown. John McKee gave a short talk on "Spiral Tendency in Blind Flying," demonstrating many of the sensations by means of a whirling chair.

University of Detroit. On January 23rd the Student Branch held a meeting which featured the presentation of the Continental Trophy. This trophy is awarded each year to the Junior student at the University who has completed the best airplane design. The recipient this year was Gerald Coleman; David Riley was second. Following the presentation Major Burnette, Manager of the Municipal Airport at Detroit, spoke on "Problems of Airport Management" and Mr. Casler of the duPont Corporation gave a lecture on "Applications of Synthetic Rubber." Thirty-five members and guests attended the meeting.

University of Michigan. On December 8th and 9th about forty members of the Student Branch visited Wright Field and were shown through the laboratories. At a meeting on February 21st the sound film, "Transpacific," was presented through the courtesy of Pan American Airways. About 900 members and guests attended.

New York University. The officers of the Student Branch are: Karl Peck, Chairman; S. Meiselman, Vice-Chairman; Wilson Van Alst, Secretary-Treasurer; Frank B. Sandgren, Honorary Chairman. Meetings are held weekly during the noon hour; Branch Lectures or student papers are presented and discussed. Evening meetings are also held occasionally. At one of these Robert Boyer of Pan American Airways spoke on positions available in the aviation industry; at another, a film showing the activities of American Airlines was exhibited.

Rensselaer Polytechnic Institute. At a meeting of the Student Branch on February 15th the following officers were elected for the second semester: R. J. Cox, Chairman; H. L. Hanson, Treasurer; P. M. Fallon, Secretary. G. P. Smith presented the Branch Lecture, "Safety from the Ground Up," by Jerome Lederer. On February 22nd Prof. Hemke, Prof. Fairbanks, and Mr. Corwin summarized the Eighth Annual Meeting of the Institute. Forty members and guests attended the meeting.

Changes in Membership

The following changes in the membership of the Institute have occurred since the publication of the previous issue of the Journal:

Elected to MEMBER Grade

Harpoothian, Edward, A.B.; M.I.Ae.S.; Structural Engineer, Douglas Aircraft Co.
Holmes, Bradford Buttrick, Instrument Engineer, Pioneer Instrument Division, Bendix Aviation Corp.
Moon, Harold Predmore, M.I.Ae.S.; Gen. Manager, Summit Aeronautical Corp.
Niedelman, Samuel, M.S.; M.I.Ae.S.; Pres., Aviation Equipment & Export, Inc.
Redding, James Deyo, M.S.E.; M.I.Ae.S.; Asst. Chief, Aircraft Airworthiness Section, Civil Aeronautics Authority.
Walton, Edwin Colby, B.S. in Ae.E.; M.I.Ae.S.; Sales Engineer, Export Sales Div., Curtiss-Wright Corp.

Elected to Technical Member Grade

Cerny, Richard Joseph, B.S.; Draftsman, Glenn L. Martin Co.
Chin, Harry Bradford, Instructor, Boeing School of Aeronautics.
White, Maurice Donald, S.B. in Ae.E.; Jr. Aero. Engineer, N.A.C.A.

Transferred from Student Member to Technical Member Grade

J. H. Dwinnell, Computer, Aerodynamics Lab., Univ. Washington; Thomas S. Flatley, Draftsman, Lockheed Aircraft Corp.; Donald P. Frankel, Test Engineer, Allison Div., General Motors Corp.; John E. Glenn, Draftsman, El Segundo Div., Douglas Aircraft Co.; W. Raymond Graf; Bruce F. Grimm, Jr., Stress Analyst, North American Aviation, Inc.; N. Grossman, Aero. Instructor, Indiana Technical College.

Aeronautical Reviews

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

Importance of Wind Tunnel Installations for Aeronautical Research. S. Eicke. Upper limits of wind-tunnel driving power, problems of wind-tunnel research, other aerodynamic test means, and cooperation of all test methods for flight science and technique. General discussion referring to German equipment as well as that of other countries. Drawing shows layout for testing the landing of aircraft model on water. Photographs of the Potez-C.A.M.S. 160 flying boat model for the transatlantic C.A.M.S. 161 flying boat, and of the free-flight wind tunnel of the N.A.C.A. are given. *Luftwissen*, November, 1939, pages 283–286, 3 illus.

Aircraft Design

Constant-Velocity Aerofoils. J. L. Taylor. Theoretically derived profiles of thin sections suitable for high speeds. For the case of the thin cambered airfoil considered, excess velocity at a point on the back is equal to the defect of velocity at the corresponding point on the face, which is the same point in space, since thickness is ignored. The required solution developed gives the shape of a camber curve developing constant suction at zero nose-tail incidence. The case of an airfoil having a flat face, *i.e.*, camber equal to half the thickness, is also considered. Independent verification of the form of the constant-pressure camber line has been obtained, using Theodorsen's well-known graphical method but reversing the usual procedure. *Aircraft Engineering*, December, 1939, page 441, equations.

The Modern Twin-Fin Tail. B. S. Shenstone. Fins inset from the tips, and tails or wings with dihedral are considered. Effect of inset fins on induced drag, amount of inset, a simple method of investigation, and side loads on fins are discussed. It is concluded that end-plate fins are better than inset fins, as far as their effect on tailplane efficiency is concerned. As long as inset fins are outboard of the half semispan position, efficiency is considerably higher than that of a single-fin tail, but if fins are inboard of this position, they are hardly better than a single fin. It makes no practical difference to the tailplane efficiency if fins are all above, below, or symmetrically disposed. As is the case for end-plate fins, side loads with zero rudder angle are least for symmetrically disposed fins.

Tails or wings with dihedral are dealt with in a similar manner. It is shown that dihedral increases wing efficiency by reducing the induced drag, but to such a small extent for ordinary dihedrals as to be entirely negligible. Effect of splaying out the fins is to decrease efficiency of the tailplane compared to that with fins at 90 degrees. Continued. *Aircraft Engineering*, December, 1939, pages 442–443, 10 illus., equations.

Transatlantic Air Transport with Particular Reference to Flying Boats. A. Gouge. Several designs for airplanes and flying boats for transatlantic service are proposed. The opinion is expressed that, largely on account of take-off and landing problems, future regular air service across the Atlantic will be by large flying boats at a height of about 12,000 ft., and crossing will be made direct. Speeds considerably higher than those prevailing at the present moment must be aimed at. A flying boat at least twice the weight of those already existing or being constructed could be built. Larger flying boats still will be possible in a few years' time so far as structural materials are concerned, but further development work on engines and propellers must be carried out. It is highly desirable that work be done on compression-ignition engines.

Results of British survey flights, choice of route, design of terminal airports, high-altitude flight, effect of improvements in materials on future developments, and the compression-ignition oil engine are also discussed.

British paper which was to have been read at the joint meeting of the Institution and the A.S.M.E. in New York, cancelled on outbreak of war. *Inst. Mechanical Engrs., Jour.*, November, 1939, pages 69–79, 12 illus., 4 tables.

The Light Fighter. C. R. Tennant. Author's answers to Captain Marendaz's criticisms of his suggested design of a light fighter which was to be designed for low cost and mass production. Fighter was described and discussed in previous issues under the title of "Argument for the Light Fighter." Figures for performance were purposely very conservative, and were based on the standard Alvis Leonides 450-hp. 9-cylinder radial engine giving maximum power low down. For practical purposes an engine blown to at least 15,000 ft. would be necessary, and at this height speed would be around 350 m.p.h. Weight estimate was very conservative. Overall dimensions are slightly less than those of the Mew Gull. Alvis Leonides engine is praised and said to be the most suitable engine available. It is obtainable as a complete and interchangeable power unit with all services and connections so that it can be fitted to an airplane and be ready for flying in about an hour. Satisfactory test results and ease of production are pointed out.

The Vickers Venom light single-seater fighter of 1935 is illustrated with the comment "With the 600-hp. Bristol Aquila radial the top speed was 312 m.p.h. The span was 32 ft. 9 in. It had eight machine-guns in the wings. The Venom never went into production, which was a pity." *Aeroplane*, December 29, 1939, pages 842–843, 2 illus.

Aircraft Data and Flight Performance. H. Mueller. Estimated aircraft data for performance calculation do not entirely agree with those of the completed aircraft, or aircraft weight, drag and power output are desired for an airplane of altered construction, and so the question arises concerning their mutual effect on aircraft performance. Relations between total weight, power output and drag and aircraft performance are discussed in regard to horizontal speed, rate of climb, and range of flight. Separate variations are presented comparatively in order to demonstrate how much weight, for example, could be used at the most for improvement of power output or reduction of drag without impairing aircraft performance. *Luftwissen*, July, 1939, pages 225–228, 6 illus., 1 table, 29 equations.

Stress Analysis and Structures

Hydraulic Static Testing of Airplane Structures. C. Tilgner, Jr. Jack and load maintainer valve developed by G. E. Beggs, and method of static testing successfully used by the Grumman Aircraft Engineering Corporation for the past three years are described. There are no inertia effects, and the mechanism can be kept far enough away from the specimen being tested to permit thorough inspection. Once the set-up has been designed and checked the applied load at each point of the entire system can be checked at one point. Innovations introduced since the system was first employed, and applications for testing different structural units are discussed. *Aero Digest*, January, 1940, pages 54–56, 13 illus.

Increase of Torsional Stiffness of a Prismatical Bar Due to Axial Tension. M. A. Biot. Author's theory of elasticity of the second order is applied to calculate the increase of torsional stiffness of a prismatical bar when an axial tension is initially imposed upon it. It is found that the classical shear stress distribution is not affected by the axial stress. An increase of torsional stiffness is produced due to the fact that the boundary condition over the cross-section contains not only the shearing stress but also the product of the axial stress by the rotations. This increase of torsional stiffness turns out to be proportional to the polar moment of inertia of the cross-section with respect to its center of gravity. Examples are shown for the case of a strip of rectangular cross-section, and a circular thin-walled cylinder split along a generator. *Jour. Applied Physics*, December, 1939, pages 860–864, 3 illus., 28 equations.

Dornier-Stressed-Skin Structures. L. Petzold. Experiences of the Dornier-Werke G.m.b.H. in the development of a new method for mass production of fuselages, and results obtained with the stressed-skin main plane for the Do.24. New method was evolved by Dr. Spiesz to build the fuselage from detail-assembled, or prepared, components—such details would consist of panel sections, longerons, stringers, formers, and bulkheads. These parts are manufactured in separate shops and are grouped together according to the capacity of each shop, strict supervision being maintained to ensure complete interchangeability. Parts are so arranged and designed that final assembly of the fuselage is little more than a bolting-up or riveting process. Sizes of parts for curvature of the fuselage are determined from a mockup. Mockup construction, and preparation of the detail cutting and drilling jigs are described, and a few detail points which require careful watching in the preparation for fuselage production are pointed out.

The stressed-skin wing structure of the Dornier Do.24 is described. In order to economize in weight and make every member contribute to the strength of the whole, the design was arranged to cause as even a distribution of load as possible. Engineers in the experimental section of the Dornier-Werke consider that it would be possible to build structures in which the external skin (including all openings in the surface) would take stresses of the order of 37,000 lb./sq.in. In this case a smooth skin would be used in conjunction with a corrugated inner one. British Air Ministry translation from Jahrbuch 1938 der Deutschen Luftfahrtforschung. *Aircraft Engineering*, December, 1939, pages 451–454, 21 illus.

Magnesium Castings for Airframe Production. Results of three years of progressive experiment made by the Phillips and Powis Aircraft, Ltd., have been so encouraging that more than 300 different castings of magnesium alloys are used for both highly stressed and unstressed parts in their latest product, the Miles Master advanced trainer now in quantity production for the R.A.F. Tests undertaken by the company on tailwheels to prove this alloy suitable are summarized. Marked increases in tensile strength, elongation and impact and fatigue strengths produced in magnesium alloys by solution treatment are pointed out. Machining principles for these castings are dealt with. R.A.E. alkaline dichromate process used at the Phillips and Powis plant for protecting castings from corrosion is described. Properties of some of the castings used are discussed. Various airplane parts made of these alloys are illustrated. *Aeroplane*, December 8, 1939, pages 721–723, 15 illus.

Plastics and the Aeroplane. Eight main types of plastics which find application in the construction of aircraft are outlined and methods of working them are described. Particular applications of some of these plastics to the production of parts for aircraft are discussed, including: transparent plastics as substitutes for glass; laminated plastics for propeller blades; adhesives used; plastics for instruments and dials; developments in electrical insulation; and bearings. *Aeroplane*, December 8, 1939, pages 708–709, 3 illus.

Rubber in the Aeroplane. Applications of Neoprene (Grades E, G, etc.), Buna (Perbunan, Perbunan extra, etc.), and reaction products of metallic polysulfides and dihalogenated hydrocarbons (Thiokols, Vulcaplas, etc.) in airplane parts. Selection of natural rubber, which is considered superior to Neoprene for a unit intended to absorb vibration, especially if accompanied by a considerable applied load, or if it is subjected to repeated flexings and deformation in service, is considered. Rubber for couplings, and mountings for aircraft-engines, instruments, and wing tanks, and the advantages gained by using shear mountings for aircraft engines are taken up.

Applications of rubber-bonded-to-metal units are described and load-deflection data are given which were obtained on tension, shear, and compression mountings of rubber-duralumin, a natural rubber quality of 50 degrees Shore hardness being used. Synthetic-rubber as a sealing medium for fuel tanks, and a method of producing sheet-aluminum tanks with Neoprene-fabric strip are dealt with, and disadvantages of using polysulfide reaction products as sealing medium are outlined. Other applications for which synthetic rubbers (Neoprene) are employed in airplane construction are given. *Aeroplane*, December 8, 1939, pages 710–712, 9 illus.

Solution of Rectangular Clamped Plate with Lateral Load by Generalized Energy Method. G. Pickett. With the aid of the general formulas presented, the energy method may be readily applied for obtaining moments and deflections for any lateral load on a clamped rectangular plate. Mathematical computations given illustrate the application of the formulas. Method is compared to others in regard to accuracy and limitations are pointed out. For fair accuracy with all but a few types of loading, it has advantages over other known methods. It does not give as good results for concentrated loads as for distributed loads, and is inferior to Timoshenko's method for a concentrated load at the middle. *Jour. Applied Mechanics*, December, 1939, pages A168–A170, 1 illus., 3 tables, 5 equations.

The Stability of the Multispan Elastically Supported Bar. A. Schleusner. Method of calculation is described. *V.D.I.*, September 16, 1939, pages 1042–1043, 5 illus., 5 equations.

Torsion and Flexure. C. Gurney. Reason underlying the solution of two problems of constant recurrence in design is presented for the engineer of limited mathematical knowledge. Solutions for flexure of a thin blade, and torsion of a thin-walled tube have been obtained without use of stress functions—compatibility being introduced as a geometric condition. Shear deflection of a thin blade is shown to be the same as deflection obtained by assuming shear distribution uniform across the depth of the section—a conclusion different from that drawn in well-known "Strength of Materials" textbooks. If axial warping is prevented at the root section, it can be shown that deflection will be less than that given. The Bredt formula and first terms of Duncan's series approximation for torsion of thin-walled tubes are obtained by a method similar to that used for flexure, and significance of the first terms of Duncan's series approximation is explained. It is said that solutions for flexure of plate web girders and thin-walled tubes can be obtained by a process identical with that used for flexure of the blade. *Aircraft Engineering*, December, 1939, pages 437–440, 14 illus., 23 equations.

Aircraft Accessories

Aircraft Components and Materials. Alphabetically arranged review of the products of over 400 ancillary firms. *Flight*, December 7, 1939, pages 467–480, 36 illus.

Aircraft Hydraulic Equipment. Hydraulic operation of moving parts such as flaps, undercarriages, and gills is discussed in detail, including: pin-jointed jacks; high-pressure pumps; points to be observed during installation of equipment; and advantages offered by hydraulic equipment. Dowty nutcracker undercarriage for hydraulic operation, Dowty self-locking retracting wheel, Dowty ground-test pipe coupling, Dowty live-line hydraulic pump, and the hydraulic circuit actuated by the Dowty high-pressure live-line engine-driven pump are illustrated. *Aeroplane*, December 8, 1939, pages 724–725, 8 illus.

Helical-Spring Shock Absorber with Oil Damping. Shock absorber for aircraft having helical springs and oil damping, and recently developed by Elektron Company, Cannstatt. Short description and cutaway drawing. *Luftwissen*, November, 1939, page 292, 1 illus.

The Problem of Ancillary Power Services on Aircraft. R. H. Chaplin and F. Nixon. It is proposed: to retain electricity and hydraulics only; to drive generators for these two services off main power unit or units; to standardize a pressure for hydraulic service, this pressure to be as high as is practicable (3000 lb./sq.in. for brakes and jacks and 1000 lb./sq.in. for gun turrets); to retain direct current at 24 volts for electrical service. To adopt, as an interim measure, generation of pneumatic energy, where necessary, by small electrically driven pump unit until new equipment becomes available.

Discussion covers: reasons for supplementing electricity by hydraulics; replacement of vacuum and compressed air and reasons for their elimination; independent power unit for services; high-frequency high-voltage alternating current and that of normal voltage and frequency; main power unit or units as source of energy; electrical and hydraulic generators; review of hydraulic situation; emergency operation. The engine viewpoint is also discussed. Appendices include: list of power services on aircraft; basic source of power; characteristics of hydraulic pumps in service; and descriptions of various types of accessory gear boxes and auxiliary power units. *Royal Aeronautical Soc., Jour.*, December, 1939, pages 942–974 and (disc.) 974–991, 14 illus, 3 tables.

Aircraft Manufacture and Production

Modern Machinery for the Production of Aircraft and Engines. Machines and tools are described and their application in aircraft production are reviewed, including: presses, boring machines, riveting machines, grinders, milling machines, tapping machines, contour shapers, routers, lathes, shrinking machines, draw benches, sawing-filing machines, welding equipment, motor fan, spacing device, shears, drilling machines, finishing machines, die-handling trucks, tools, hardness tester, nibblers, polishing wheel, rolling machines, shapers, sawing machines, die holders, lapping machines, spray outfit, compressor, and levelator. Addresses and other data concerning the manufacturers whose products are described appear in a directory section. *Aero Digest*, January, 1940, pages 67–99 (alternate pages) and 128–162, 60 illus.

Use of the Hydraulic Press. H. O. Thweatt. Hydraulic press operations on parts for aircraft structures are described, including presses, dyes and pads employed, and a double-action hydraulic press developed by the Lake Erie Engineering Corporation which is of sufficient size to handle practically all of the deep-drawn parts. By use of a secondary platen above the main moving platen as a means of clamping the sheet while drawing, the press permits the drawing of all shapes and sizes. Various types of dies can be used with the press to suit any production. While designed for double-action deep drawing, the press can also be employed for deep forming with rubber using the single dies, and can be fitted with a rubber pad holder and bolster for pressing of small parts. *Aero Digest*, January, 1940, pages 36–37, 56, 6 illus.

Flush Riveting in German Aircraft Construction. W. Pleines. Rivet connections on the surface of high-speed aircraft should be such that they produce no additional drag. Technical requirements of flow to be fulfilled are discussed. The flush-riveting method is said to have been developed in Germany. Different forms of rivet connections and their production are described in detail.

First issue—Rivet connections for flush riveting; production of rivet holes (drilling and sinking); installation and tightening of rivets; and upsetting and heading of rivets.

Second issue—Various forms of rivet connections; special experiences in practice; indirect riveting; special rivet setter; and correct rivet die form. *V.D.I.*, September 16 and 23, 1939, pages 1037–1041 and 1057–1060, 44 illus.

Light Alloys and Production. Procedure for casting, forging, pressing, drawing, spinning, extruding, and machining aluminum- and magnesium-base alloy components for aircraft are discussed and advantages and limitations of each from the practical and economical standpoints are pointed out. Mueller combined hydraulic press and drop hammer for sheet forming, the Bigwood sheet-metal stretching machine for forming large sheet work such as components for aircraft wings, horizontal extrusion press in operation at the Reynolds Tube Company, and a propeller being formed in the Eumuco roll forging machine are illustrated. *Aeroplane*, December 8, 1939, pages 704–707, 6 illus.

Spot Welding for Production. "Although there has recently been a considerable application of the process abroad there has been a justifiable reluctance on the part of the Air Ministry to extend sanction for spot welding until absolute proof of its reliability for each application has been obtained. Further difficulties have been caused by the necessity of a protective treatment of the surfaces of some of the alloys. They are given an insulating skin through which the welding current cannot pass."

Conditions most favorable to successful spot welding of light alloys, materials which give the best results, and physical limitations to the use of welding machines are discussed so that those engaged in the aircraft industry may have a groundwork from which to investigate the application of spot welding.

Greater care necessary for welding of light alloys than steel is pointed out and instructions are given in regard to condition of surface of sheet, thickness of material, shape and character of electrodes, time, current, and pressure. *Aeroplane*, December 8, 1939, pages 718–719, 4 illus., 1 table.

Tools for the Workshop. Pels 100-ton folding press; Wolf Torky TH.2 and TP.2 hand drills; American Harvey Model 106 convertible spot welder; and American Fafnir mechanically sealed ball bearings. Descriptions. *Aircraft Engineering*, December, 1939, pages 460–461, 4 illus.

Welding Technique in Aircraft Construction. K. Queitsch. Translation of first part of the German Air Force welding handbook, "Schweisstechnik im Flugzeugbau," and covering: strains caused by heating; theory of "contra-heating"; manipulation of blowpipe and welding rod for welds in steel tube; welding-rod technique; butt welding of steel tubes; welded T-joints at tubular struts, operation and sequence; welding of oblique tubular joints; welding of cross joints of steel tubes; angle joints of steel tubes; braced steel-tube angle joints; welding of gusset plates (web reinforcements) to tubular joints; and arrangement and sequence of seams for the prevention of overlapping.

Editorial states that it is the most practical and complete treatise on the subject that has yet been published anywhere. To be continued. *Aircraft Engineering*, December, 1939, pages 455–458, 23 illus.

Aviation. Current rate of production of airplanes is set at a maximum of 1250 a month, or 15,000 a year, and by the end of 1940 the aircraft industry will be able to produce at a rate corresponding to the output of 25,000 airplanes annually, according to figures issued by the Aeronautical Chamber of Commerce. Engine production is rated at 16,000 units a year, but, by December 1, 1940, those companies producing high-powered engines will have an annual productive capacity of 25,000 engines of at least 1000 hp. each. Present position of the aircraft industry, training of pilots and air-transport gains are briefly reviewed. *Iron Age*, January 4, 1940, pages 141–142.

Aircraft Performance Testing

Procedure for the Objective Measurement of Record Flight Speeds. E. Weber and W. Rossmann. New apparatus developed by Askania in cooperation with the D.V.L. for measuring record flight speeds on the 3-km. basis, and the procedure employed for measuring the record speeds attained by Flight Captain Dieterle on March 30, 1939, over Oranienburg in his flight in the Heinkel 112 U. Long detailed description. D.V.L. report. *Luftwissen*, July, 1939, pages 229–232, 5 illus., equations.

Aircraft

Problems of Recognition. First issue—Difficulties in identifying aircraft in flight, and first of a series of photographs of Allied and German airplanes to be published every week for practice in identification.

Second issue—Characteristics enabling identification of the Dornier Do.17 two-engine reconnaissance bomber and the Bristol Blenheim fighter-bomber in flight, and aircraft of the opposite side with which they might be confused. Two more photographs are given to provide practice in recognition. Short notes. *Aeroplane*, December 22 and 29, 1939, pages 800 and 843, 4 illus.

The Opposing Fighters. The Hurricane's designer, S. Camm, on the Messerschmitt Me.109, and the editor's comparison of Allied and enemy single-seaters, with accent on fire power. Mr. Camm claims: that strength factors of the Messerschmitt and Heinkel fighters are seriously below those of the British fighters; that maximum power altitude of the Messerschmitt is lower by 5200 ft., although the engine gives 100 hp. more; that their speeds are not as fast as that of the Hurricane; that speed of the Me.109 is not obtained by aerodynamic cleanness; that method of retracting the Me.'s undercarriage appears a very inferior job; that it is unsatisfactory for night flying; that it has been consistently outmaneuvered by Allied fighters; and that owing to the liability of partial stall in a high-speed turn, it appears that it can be evaded by British medium bombers.

The editor discusses the difficulty indicated with overheating of the Daimler Benz and Junkers cannon-engines, and the greater load of ammunition carried by the Me.109, particularly for weapons in the wings, and considerably more per gun than the British eight-gun fighters. He reviews the armament of the French Curtiss, the Morane, Bloch 151, and Caudron light fighter, and refers to reflector sights now used. *Flight*, December 14, 1939, pages 490e–490h, 491, 15 illus.

Australia Goes to War. Activities in preparing for the part Australia will take in air warfare are reviewed briefly touching upon: production of aircraft in Australia; preliminary training of pilots; R.A.A.F. present concentration on training instructors to deal with the flood of partially trained men being turned over by the schools; and construction of new bases. Reference is made to sabotage of civil aircraft, and to unprecedented prosperity of civil airlines since the start of the war. *Aeroplane*, December 8, 1939, page 684.

Canada

Canadian Equipment. First Bristol Bolingbroke (Type 74583), described as a "prototype general reconnaissance bomber," has been flown by Fairchild of Canada which is building a series of these machines for the Royal Canadian Air Force. Machine is said to be almost identical with the Mark IV (long-nosed) Blenheim although it differs in one or two details (length of exhaust pipes). Without interfering with production for England, France, or the United States, 23 Harvards have been delivered to the R.C.A.F. Perseus-engined Lysander IIs and Fairey Battles are also used. Brief reference. *Flight*, December 7, 1939, page 481.

France

Mauboussin 200. Single-seater low-wing light monoplane for training in piloting pursuit planes. Regnier 4-EO 95 - hp. engine. Speed 285 km./hr. Landing speed 95 km./hr. Flight duration 3.75 hours. Details of construction, characteristics, and performances. Brief. *Luftwissen*, November, 1939, page 294, 1 illus.

Germany

The Dornier Do.17 and Do.215 Bombers. Dornier Do.17 two-engine bombers have been used by the German Air Force more than any other type for numerous photographic reconnaissance flights over France and England. Their defense is poor and they are not fast enough to do without it. There-

fore many have been shot down. The Do.17, as usual with German designs, is built for production rather than efficiency.

The Do.215, developed from the Do.17, is identical with it except for a redesigned nose for larger accommodations for the crew, some strengthening of the structure, and installation of more powerful engines. Control wheel is slung from the roof instead of being mounted on the normal column. Crew has been increased to four (pilot, navigator, radio operator, and bomb aimer), all except the pilot having movable machine guns. Members of the crew are close together and can relieve each other of different duties. Front gun has been made movable through the windscreen and fields of fire of the two aft guns have been increased. For the rest, the Do.215 is built on the same jigs as the Do.17.

Three different types of engine have been used on the Do.17. With two Daimler Benz D.B.600 Gs engines top speed is 292 m.p.h. at 14,800 ft., service ceiling 30,400 meters, and range 965 miles. Extra tanks to bring fuel load to 485 gal. may be installed for reconnaissance, and range with three cameras is 1240 miles.

Top speed of the Do.215 when powered by two 1150-hp. Daimler Benz D.B.601 As engines is 312 m.p.h. at 16,400 ft., service ceiling 29,600 ft., and range 965 miles. Extra tank to bring fuel load to 568 gal. may be installed, and range with three cameras is 1500 miles.

Long descriptions of several versions of the Do.17, and of the Do.215, as well as construction, characteristics, and performance of both are presented, and experience in flying the Do.17 is related. Photographs of both, cutaway drawing of the Do.215 showing location of equipment, and drawing of the front portion of the Do.17 are included. *Aeroplane*, December 22, 1939, pages 808–810, 9 illus.

Messerschmitt 110 Attack Airplane. A. Frachet. Due to its power the Me.110 is the fastest of the German airplanes in service but does not possess the maneuverability either of the French Breguet 692 or of the Potez 63 by which it was inspired. Me.110 is powered by two D.B.601 engines each developing 1360 hp., and has a top speed of 600 km./hr. at 5000 meters. Description and brief comparison with these French airplanes. *Les Ailes*, December 7, 1939, page 3, 3 illus.

Some German Prototypes. H. F. King. A few details are given for some prototypes, some of unorthodox design and some rumored to have been adopted or possibly already in service. *Flight*, December 28, 1939, pages 530a–530d, 533, 11 illus.

Technical Review. Klemm Kl.105 two-seater low-wing monoplane for training, sport, and touring. Zuendapp Z.9-92 50-hp. engine. Top speed 150 km./hr. Klemm Kl.107 two-seater low-wing monoplane designed for the same purpose. Hirth HM.504 100-hp. engine. Top speed 200 km./hr. Details of construction, characteristics, and performances. Brief. *Luftwissen*, November, 1939, page 293, 2 illus., 2 tables.

Zlin XV. Czechoslovakian two-seater low-wing training and sport aircraft. Top speed: with Zlin Toma 4 105-hp. engine 230 km./hr.; with Walter Minor 4 85-hp. engine 210 km./hr. Few details of construction, characteristics, and performances with both engines. The Zlin Toma 4 engine is also briefly described. *Luftwissen*, November, 1939, page 295, 1 illus.

GREAT BRITAIN

British Aircraft Production. E. C. Shepherd. Careful organization should ensure that the production of a particular type of airplane should continue at full blast in two or three of the works which are making it while the change to a new type is being arranged at two or three other works. Production can be made to overlap in this way more easily now that the work is spread than it could at the beginning of the expansion period, when only one factory as a rule was engaged on the manufacture of one type. Present satisfactory status of the British aircraft industry is commended, and replacement of production of one type with another is discussed. *Aeroplane*, December 8, 1939, pages 702–703, 1 illus.

British and Empire Constructors of Aircraft and Aero-Motors. Photographs and particulars of 90 British airplanes and 33 British aircraft engines produced by 46 aircraft constructing firms and 18 aircraft-engine constructors are presented. There are also the names of 21 aircraft constructors in the British Empire which are adding to the war-time output.

Of the airplanes, 45 are military types of which 31 are first-line types, 8 are trainers, target towers, troop carriers, and 6 are prototypes which have not been put into production. There are 12 transport types and 27 lighter civil airplanes. Of the 33 aircraft engines, three types are liquid cooled, 30 aircooled, 14 are radials and 17 inline. There are seven types of 1000 hp. or more.

Besides photographs, a few details, characteristics, armament, and, in most cases, performances are given for many British aircraft, including civil transports, light tourers and trainers, light single-seaters and new designs of large transports. *Aeroplane*, December 15, 1939, pages 741–757, 97 illus.

Maintaining Our Sea Routes. Short Sunderland long-range flying boats are the biggest airplane in service in the R.A.F. and are flying thousands of miles every day. Sunderland's four 1010-hp. Bristol Pegasus engines give it a top speed of 210 m.p.h. at 6250 ft. At an overload weight of 49,870 lb. maximum range is 2880 miles. Photographs of production line, and interior and exterior of the boat. *Aeroplane*, December 8, 1939, page 697, 3 illus.

ITALY

Fiat C.R.25. Three-seater low-wing monoplane for bomb dropping, long-range reconnaissance, and defense. Two Fiat A.74 R.C.38 840-hp. double-row radial engines. Two fixed machine guns in the bow of the fuselage, one flexible gun in the sunken turret on the top of the fuselage. Top speed 460 km./hr. Climb to 6 km. 13.0 min. Range 1900 km. Few details only of construction, armament, bomb load, characteristics and performances. *Luftwissen*, November, 1939, page 294, 1 illus., 1 table.

U.S.A.

Cubs for 1940. New three-place Piper Cub "Cruiser" and a redesigned Cub "Coupe," both two-seater high-wing monoplanes, are described. Wing span of the "Coupe" is 36 ft. 2 in., and placard speed is 100 m.p.h. when powered by either a 65-hp. Continental or Lycoming engine. Cruising range is 382 miles. Wing span of the "Cruiser" is 35 ft. 5.5 in., placard speed is 110 m.p.h., and power plant is furnished by the new Lycoming GO-145C 75-hp. four-cylinder horizontally opposed engine. Cruising range is 320 miles. Description. *Aero Digest*, January, 1940, pages 59–60, 174, 3 illus.

Description of the Cub Cruiser. *Aviation*, January, 1940, page 54, 2 illus., 1 table.

Curtiss Falcon Trainer. Curtiss Falcon 22 all-metal two-seater basic combat and all-purpose trainer (Wright Whirlwind 9-cylinder engine) which has just completed flight tests, has been designed specifically for training "fighting pilots," and has been contracted for by a foreign government. Airplane has a wing of special design which provides greatly improved stall and spin characteristics and retractable landing gear. **Provision has** been made for all types of training activities, including gunnery, bombing and instrument flying. Airplane is smaller than the Curtiss Hawk 75A pursuit, but incorporates the latest in structural design. Photograph and few details of structure. *Aviation*, January, 1940, page 49, 1 illus.

A Decade of Grumman Progress. Development of the Grumman Aircraft Engineering Corporation since its organization in 1930, and military aircraft produced are described. *Aero Digest*, January, 1940, pages 48–49, 52, 174, 13 illus.

The Navy's Newest Patrol Bomber Arrives for Tests. T. N. Sandifer. Rated as the world's largest amphibian airplane, the Consolidated Model 28-5A has new tricycle landing gear which, like the wing-tip floats, is retractable and covered by flush metal hatches when the plane is in flight. All three wheels are retractable by operation of a single lever, and the wheels, including oleo shock struts, all disappear into the hull in wells covered by automatically closing hatches. There is a gun turret forward of the cockpit in addition to other armament. Approximate gross weight is 12 tons but the ship is capable of taking off when weighing more. Wing span is 104 ft. Amphibian is able to fly from San Francisco to New York and to continue on for 1000 miles beyond. Description particularly of landing gear. *U.S. Air Services*, January, 1940, pages 23–24, 1 illus.

Description of landing gear. *Aviation*, January, 1940, page 49, 1 illus. *Western Flying*, January, 1940, page 32, 1 illus.

The North American NA-57 for France. French NA-57-Et.2 Combat Trainer is a two-seater low-wing monoplane with fixed cantilever undercarriage and 420-hp. Wright Whirlwind R-975-E3 engine rated on 80-octane fuel. Trainers are being turned out at the rate of 40 per month. North American training airplanes are in service with the air forces of 15 nations. Description of the NA-57. *Aeroplane*, December 22, 1939, page 813, 1 illus.

Timm Two-Place Trainer. Timm Trainer two-place open tandem military-type low-wing training monoplane. Engines of 125 to 220-hp. may be used. Estimated performance based on 160-hp. engine is 137 m.p.h. top speed. Climb 1026 ft./min. Service ceiling 17,800 ft. Cruising range 500 miles. Short description of construction. *Aviation*, January, 1940, page 53, 1 illus.

To a European Formula. New Martin 167W multipurpose monoplanes of the French Air Force have made reconnaissance flights over German lines. "These machines are essentially similar to an attack bomber developed by the U.S. Army." A description is given of the "167W, which is exactly similar to the French type." New Vultee fighter now called the Vanguard is illustrated and is said to be among the world's fastest military aircraft. *Flight*, December 28, 1939, page 525, 2 illus.

Twin-Engined Cessna Model T-50. Model T-50 five-place low-wing monoplane is powered by two Jacobs L-4MB 225-hp. engines. Wing span 41 ft. 11 in. Cruising speed 191 m.p.h. Cruising range 1000 miles. Long description. *Aero Digest*, January, 1940, pages 64, 174, 4 illus.

Long description and drawing of landing mechanism. *Aviation*, January, 1940, pages 46–47, 4 illus., 1 table.

Few details. *Western Flying*, January, 1940, page 32, 1 illus.

Waco Model E Biplane. Models E four- to five-place biplanes are described in detail. Model ARE is powered with a Jacobs L-6 engine rated at 300 hp. at 3700 ft. Model SRE with a P & W Wasp Junior SB engine rated at 400 hp. at 5000 ft., and Model WRE with a Wright Whirlwind R-975-E-3 engine rated at 420 hp. at 1400 ft. Wing span 34 ft. 9 in. Maximum speed 204 m.p.h. for the Model WRE. *Aero Digest*, January, 1940, page 63, 4 illus.

Long description. *Aviation*, January, 1940, pages 44–45, 5 illus.

Few details. *Western Flying*, January, 1940, page 32, 1 illus.

Aircraft Refueling in Flight

Flight Refueling over the Atlantic. Sir Alan J. Cobham. British part of the Atlantic crossing of 1939 was made possible by the practice of refueling in the air. Imperial S.30 flying boats made 16 journeys across the Atlantic during the period of operation (August 5 to September 30), on 15 of which the machine was refueled in air. Time required from moment when contact is first made until gasoline is turned off takes 10 to 15 min., and time required to transfer 800 gal. of fuel is about 7 min., average rate of flow being about 110 gal./min. Preparations for the refueling flights at Newfoundland, refueling personnel, and operations are described. Two Harrow tanker airplanes are used. If connection between the two aircraft should be broken involuntarily the whole system of pipe and receiving cup is automatically flooded with methyl bromide against risk of a spark. *Aeroplane*, December 29, 1939, pages 826–827, 2 illus.

Air Transportation

French Transatlantic Plans. First of France's four new six-engine flying boats for transatlantic mail service, the 40½-ton Cams 161, and only one which will be definitely completed, has made its first trial flights. If the French parliament approves, a mail service to the United States will be started in the spring. Besides the new boat, three substratosphere four-engine 24-ton Farman landplanes will be used as well as an American flying boat which it is now tentatively intended to order. Since the Farmans take off with difficulty when loaded up to 24 tons, the minimum weight at which enough fuel for an ocean crossing can be carried, the possibility of refueling in air is being considered. A civilian version of the 30-ton four-engine experimental Sikorsky patrol bomber appears the most quickly available suitable American boat. Brief note. *Flight*, December 7, 1939, page 466.

Gliders

Gliding Practice in Flight at High Altitudes. W. Spaete. Two factors to be taken into consideration in glider flights at high altitudes, namely effects of cold, and low density with reference to oxygen deficiency of air, are discussed. Design of cockpit, clothing required, effect of cold on instruments, effect of cold and pressure changes on human organisms, use of oxygen masks, use of parachutes, and dangers of flight in a storm cloud are considered. *Luftwissen*, November, 1939, pages 288–290.

Propellers

Vibration Characteristics of Aircraft Engine-Propeller Systems. C. M. Kearns. Modes of vibration of a complete engine-propeller-mount system are described in regard to modes involving engine-crankshaft torsional oscillations; modes involving engine whirl motions in space, and vibrations involving neither engine-crankshaft torsional oscillations nor engine whirl. Factors influencing resonant frequencies, and aerodynamic damping and internal hysteresis in a propeller, present methods of solving vibration prob-

lems, and future trends are discussed. It is estimated that if all vibratory excitations were removed from the propeller, the specific weight could be reduced to approximately 0.20 lb./hp. As an example of this, stress measurements on a propeller operating at 200 percent power and 100 percent speed rating on an electric whirl rig indicated that the stress reached only 15 or 20 percent of allowable alternating value for the particular design. *S.A.E. Jour. (Trans.)*, December, 1939, pages 540–548, 14 illus., 2 tables, equations.

Acoustics

The Computation of the Composite Noise Resulting from Random Variable Sources. E. Dietze and W. D. Goodale, Jr. Statistical method of combining noise sources is applied to computing the meter reading which would be obtained on a sound level meter when used to measure room noise resulting from the random concurrent operation of a number of intermittent or continuous noise sources. Method makes possible the engineering analysis of noise problems. Applications of the method in the solution of practical problems is illustrated. *Bell System Technical Jour.*, October, 1939, pages 605–623, 6 illus., 1 table, 10 equations.

Aircraft Instruments

A New Electro-Sonic Altimeter. J. H. Jupe. New height-measuring instrument, recently introduced by Henry Hughes and Son, Ltd., has been developed for aircraft on marine sounding-apparatus lines. Power is obtained from a 24-volt accumulator through a motor-driven alternator. Sound is generated by running the motor up to a speed of 10,000 r.p.m. and short circuiting the generator rotor across the speech coil of a moving-coil loudspeaker. One-hundredth of a second is the duration of the impulse and it is repeated at 1-sec. intervals. On its return to the aircraft the reflected sound wave is picked up again by the receiver unit which consists of a frequency selective moving-coil microphone preceded by an acoustic filter chamber to remove engine and other unwanted noises. Maximum heights at which instrument will work are 750 ft. over water and 450 ft. over grassland. Description. *Aircraft Engineering*, December, 1939, page 444, 1 illus.

Mechanical Brain. By means of the new Librascope flight computor used on the airlines, the pilot can determine every factor of his flight plan in one minute or less. Variable factors represented by a pointer knob on the flight computor include: wind velocity, wind direction, true course of flight, gross weight, time elapsed, pressure altitude, free air temperature, carburetor air temperature, horsepower, and engine r.p.m., while the indicator dials are calibrated to show total distance, true-course ground speed, drift angle, indicated air speed, total fuel consumption, manifold pressure required, and b.m.e.p. Use of the Librascope is described. *Western Flying*, January, 1940, pages 21, 24, 2 illus.

New Applications of Variable-Reluctance Method to Aircraft Instruments. H. H. Bruderlin. Development of accelerometers for stress and vibration measurements in flight, undertaken by the Douglas Aircraft Company, is discussed in detail, and equipment used in test flights of the DC-4 for producing simultaneous records from four separate sources is described and illustrated.

Accelerometer for measuring load factor applied to the structure during landing, dives and various maneuvers; instrument for measuring slow vibrations of small amplitude where much high-frequency vibration is present; requirements of an accurate accelerometer; experimental accelerometer developed by the company; new accelerometer designed for conversion into a strain gage when required; instrument developed, still using a balanced inductance bridge, that responded to torsional but not to linear motions; linear displacement pickup having characteristics similar to those of the torsional instrument and made by mounting side by side two torsion pickups that are slightly off balance; design of pickup; and alterations in the original circuit for the use of four channels simultaneously. *Instruments*, December, 1939, pages 324–326, 4 illus.

New Method of Testing Accelerometers. B. W. Woolard, National Bureau of Standards. By means of the new method described, single-component accelerometers can be subjected to practically simple harmonic acceleration which is either continuous or has a duration of a selected part cycle or number of cycles. Frequency and amplitude of acceleration are controllable within reasonably wide limits. Turntable apparatus is modified by addition of a system of two belted pulleys, one fixed to the stationary base of the turntable and the other located at the rim of the turntable and free to rotate about its own axis. Accelerometer is mounted upon a plate connected to the rim pulley by means of a friction clutch. Apparatus was constructed at the request of the Bureau of Aeronautics.

Test apparatus developed, apparatus used at the National Bureau of Standards, and operation for steady acceleration, for continuous simple harmonic acceleration, and for part cycle of simple harmonic acceleration are described in detail. *Instruments*, December, 1939, pages 322–323, 326, 2 illus.

United Air Lines' Instrument Servicing. Special instrument developed by United's instrument shop for grading bearing balls used in gyroscopic instruments by use of quartz optical flats; individual-instrument agitated pressure chamber designed in the shop for testing barometric scales and balance on altimeters as well as calibrating rate of climb indicators; special equipment for testing tachometers, pressure gages, and vacuum gages, mounted on three panels; and mercury reclaiming device built in the shop for purifying mercury drained from instruments. These instruments are illustrated with a brief description in the captions. General discussion only of United Air Lines' operating methods. *Instruments*, December, 1939, pages 320–321, 327, 4 illus.

Airports and Equipment

Aviation on the Ground. Form to give to military aviation fields in order to meet the requirements of rapid construction, good camouflage and minimum vulnerability, as well as of easy exploitation. Colonel Ssegredi had proposed the construction of runways radiating from the same point, but this proposition now appears questionable. Principal requirements which the arrangement of the runways should satisfy are analyzed from the standpoint of protection against aerial attack, exploitation of the ground, and work of construction. Various arrangements of runways are described and illustrated including three different arrangements for three-runway landing fields in which the axis of the runway would be usable up to 30° with the direction of the wind, and three different arrangements for four-runway landing fields in which the angle of the direction of the wind with the axis of the runway would not exceed 22.5°. *Rev. de l'Armée de l'Air*, September–October, 1939, pages 483–487, 1 illus.

Electric Supply in the Field. Johnson self-contained portable gasoline-electric generating set is available in six models. Type 30 C.P. is a miniature grid system operating at standard voltage and frequency, providing both power at 400 volts and lighting at 220 volts. Ford V-8 gasoline engine can be converted to run on coal gas. Johnson B.B-type portable air compressor for paint and dope spraying and riveting is also referred to. Few details of British equipment. *Aeroplane*, December 22, 1939, page 818, 1 illus.

Armament

Fields of Fire. Two drawings each of the following German reconnaissance bombers illustrating their blind areas and vulnerable spots: Heinkel He.111K Mk.III 4-seater (two 1050-hp. Daimler-Benz DB.600 engines, top speed with retractable dustbin extended 236 m.p.h. at 13,100 ft., service ceiling 21,000 ft., three movable machine guns); Junkers Ju.88K 3- or 4-seater (two 1200-hp. Jumo 211 engines, top speed 317 m.p.h. at 15,600 ft., service ceiling 29,800 ft., three movable machine guns); Henschel Hs.126 2-seater (one 880-hp. B.M.W. 132 Dc engine, top speed 221 m.p.h. at 9850 ft., service ceiling 28,000 ft., one fixed and one movable machine gun); Junkers Ju.87 2-seater (one 1200-hp. Jumo 211 engine, top speed 242 m.p.h. at 14,000 ft., service ceiling 27,900 ft., two fixed and one movable machine gun). Span and lengths of the aircraft are also given. *Aeroplane*, December 22, 1939, page 802, 8 illus.

A Survey of the Armament of Single-Seaters. H. F. King. In addition to the standard Model K drum-fed gun, a "twin" combination of these weapons and the "J" class gun which has a rate of fire of 1500 or more rounds/min. were reported to have been shown the British Air Minister at the Vickers-Armstrong factory. Even this astonishing gun is said to be beaten on rate of fire by a new Belgian Browning-F.N. which can fire 1800 rounds/min.

Discussion covers: Confirmed advantage of putting eight high-speed rifle-bore machine guns on the Hurricane and Spitfire; examples of the variety of gun combinations with which it is possible to arm a fighter; advantages of larger bores; fixed-gun combinations that the Fokker G-1 can take; various types of weapons being installed on fixed-gun fighter aircraft of various countries; methods of feeding ammunition; interchangeability of fixed and free guns; advantages of the 13-mm. Browning-F.N. gun; Vickers C-type aircraft gun; action of the Oerlikon gun; gun used in the Hispano-Suiza "moteur canon"; Danish Madsen aircraft shell gun and ammunition used; American Armament Corporation reasons for development of weapons of 37-mm.; A.A.C. shells; mounting of fixed guns; accessories for fixed-gun installations; and a reference only to the Prestone cooling of four Colt (Browning) 13.2-mm. MG-53 guns installed on the Curtiss P-42.

Table gives approximate data for some aircraft guns. *Flight*, December 21, 1939, pages 508a–508d, 509, 27 illus., 1 table.

Miscellaneous Equipment

British Standard Specifications. Approximate comparisons of hardness numbers (B.S.S. No. 860) and hexagonal-headed bolts (low-tensile steel) (B.S.S. 5 A.1) and hexagonal steel nuts for aircraft purposes (B.S.S. A.16). Brief reviews. *Aircraft Engineering*, December, 1939, page 454.

Fastening Device Nails Metal Parts Together. Speed Clip is a tubular-like formation of spring steel and has been developed by Tinnerman Speed Nut Company to fasten metal parts together without the need of gaining access to the opposite side of the assembly. End entering the hole is curled in while other end seats with its flange. In this entering position, tongues on either side are compressed into the body of the clip, but, with the clip fully inserted, two cam-like tongues spring out and lock the clip firmly in the hole. With slight variations, Speed Clip may be used as a permanent lock, a removable lock, or as a slideable grip type. Short description and drawings. *Iron Age*, December 28, 1939, page 27, 6 illus.

Three Rotax Aids. Rotax $2^1/_{16} \times 3^1/_{32}$-in. warning light with hinged anti-dazzle screen for aircraft instrument boards. Rotax portable starting truck for electrically operated engine starters. Rotax low-tension energy transfer booster coil system which secures correct timing of starter spark by boosting the main magnetos. Short descriptions. *Flight*, December 21, 1939, page 520, 3 illus.

Buyer's Log Book. Ozalid dry printing machine. "Safe-Line" wire rope clamp. H-P-M Model 40-H-2 molding press. Alexander Milburn Type KSC spray gun. Librascope flight computor. Knu-Rivette hand rivet and punch tool. New contactor used in A.C.E. spot welders. Guyer gauger. Precision Scientific gasoline tester. Special one-dip Detrex degreaser. Few details. *Aviation*, January, 1940, pages 58–59, 10 illus.

New Equipment. Harvey pre-heater for aircraft engines. Stackbin time-saving device for handling parts. Motor Fizik compound for depressing the pour point of oil so that it can be poured at low temperatures. FBPF-100 portable plane table developed by Freedman-Burnham Engineering Company for accurately setting and checking the pitch of adjustable-pitch propellers. Two Dow coatings, Treatment Nos. 7 and 8, for protesting magnesium alloys against salt water. Pioneer vapor-sealed manifold pressure gage. Sperry Exactor hydraulic control designed for positive control from remote installations. Automatic lighting signal in a life jacket developed by Triumph Explosives, Inc. Descriptions or few details of each item. *Aero Digest*, January, 1940, pages 167–168, 7 illus.

Parachutes

Fabric-Porosity Testing Apparatus. A few lines are quoted from the British Air Ministry Specification, DTD.69-A relating to the resistance to airflow of parachute fabrics, and the Cambridge fabric-porosity testing apparatus is described which was developed in order that this characteristic may be conveniently tested and measured in the factory. Sample of fabric is clamped over a ring of known area at the top of a hollow cylinder. By means of a separate electrically driven suction pump connected to the cylinder through a valve, air is drawn through the sample. Rate of flow is measured by an orifice plate inside the cylinder and indicated on a differential gage connected to points above and below the orifice. By valve adjustment, reading on the gage is stabilized at exactly 1.0 in. water. Pressure difference across the sample is determined by means of a Chattock tilting micromanometer which is capable of giving readings to 0.0001 in. water gage. *Engineering*, December 8, 1939, page 634, 2 illus.

Photography

Cartographic Sketch of Albania by Means of Aerial Photography. Italian Nistri aerial photographic and plotting equipment are illustrated in a short note. *Rev. de l'Armée de l'Air*, September–October, 1939, pages 526–528, 3 illus.

Military Aviation of Indo China and Scientific Research. J. Y. Claeys. Assistance rendered by the French military aviation to archeological research in Indo China by means of aerial photography. *Rev. de l'Armée de l'Air*, September–October, 1939, pages 529–544, 12 illus.

The Part of Aerial Photography in the Course of the Conquest of Ethiopia by the Italian Army. A. Cnarriou. Problem of cartography; organization;

equipment for taking pictures; cartographic work; and aerocartographic production. Photographs for this article are given throughout the magazine. *Rev. de l'Armée de l'Air*, September–October, 1939, pages 521–526, 3 illus.

Materials

Automotive Materials. Ryerson H.T.M. alloy steel which is machinable under ordinary shop conditions after being hardened to more than 450 Brinell. Machine developed by R. H. Kinkead for producing a new composite metal with better wearing qualities than competitive materials, such as tin terne and galvanized steel. Budd Wheel Company method of heat treating parts of metal parts by electrical induction. Calendered sheets of "Vinylite" plasticized resins developed by Carbide and Carbon Chemicals Corporation and said to have many of the advantages and few of the disadvantages of leather and rubber. Brief descriptions. *Automotive Industries*, December 15, 1939, pages 624–625, 1 illus., 1 table.

Metals

Fatigue Problems in Structural Design. A. V. Karpov. Fatigue diagrams of structural alloys; fatigue properties of structural elements; stress concentrations; flow of stress; riveted joints; welded joints; and welded and riveted plate girders. Graphs and drawings show: fatigue strength reduction due to surface conditions; fatigue diagram of region of possible stress variations; pulsating strength of riveted joints; flow of stress in welded joints; pulsating strength of welded joints; and pulsating strength of welded and riveted plate girders. *Metals & Alloys*, December, 1939, pages 381–388, 8 illus.

Nickel and Its Alloys. Directions in which nickel alloys have contributed to the evolution of the high-performance airplane engines of today. Nickel-iron alloys and their outstanding properties, and the properties of wrought and cast aluminum alloys containing nickel are shown in tables. Various nickel alloys used for different parts of the engine are described. *Aeroplane*, December 8, 1939, pages 707–708, 3 tables.

Corrosion and Protective Coatings

Bright Nickel Deposits. A. W. Hothersall and G. E. Gardam. Discussion of the microstructure of bright nickel deposits is continued, and effect of annealing in vacuo, stress in bright nickel deposits, porosity, effect of naphthalene trisulphonate on hardness and appearance of nickel deposits, and surface tension of solutions are considered. Concluded. Electrodepositors' Technical Society paper. *Metal Industry*, December 8, 1939, pages 493–496, 6 illus., 4 tables.

Primers for Non-Ferrous Metals. Corrosion investigation described was conducted on sheets of aluminum and magnesium alloys and Alclad which were selected because of the tremendous war-induced production increase in the aircraft industry which is one of the largest consumers of these alloys. Effect of heat treatment on mechanical properties and on corrosion resistance is pointed out, and chemical composition and physical properties of the alloys tested are given. The anodic treatment outlined in Naval Aircraft Factory Specification PT-13 which was used on the Dowmetal panels is described. Various primers and testing methods are described. *Paint & Varnish Production Manager*, December, 1939, pages 368–372, 2 tables.

The Protection of Silver by the Electrolytic Deposition of Beryllia. L. E. Price and G. J. Thomas. Experimental results with beryllium-sulfate solutions; variations of tarnish resistance and of wear resistance of the film, respectively, with time of treatment; effect of cleaning treatment on appearance of the protective film; experiments with beryllium nitrate and other solutions; application of method to service specimens; and comparison of results of this work with those of Britton. *Engineering*, December 15, 1939, pages 675–676, 2 tables.

The Struggle against Corrosion. Various methods for protecting metals and alloys against corrosion are described, including electrodeposition, electrolytic oxidation, chemical protective processes, metal spraying, Sherardizing, and Fescol processes. *Aeroplane*, December 8, 1939, pages 716–717, 3 illus.

Pickle Polished Stainless Steel. T. W. Lippert. Electrolytic polishing (anodic treatment, pickle polishing, bright pickling) of stainless steel. Processes patented by the Rustless Iron and Steel Corporation are described which employ a solution of concentrated citric and dilute sulfuric acids. Processes are claimed to be powerfully passivating in action. *Iron Age*, January 11, 1940, pages 22–26, 5 illus.

Iron and Steel

A Discussion of Leaded Steels. T. F. Robbins and G. R. Caskey. Comparison of engineering data on leaded steels which is intended to provide as accurate an estimate of leaded steels as is possible at present, and practical aspects of the fabrication of these steels. Long abstract Society for Metals paper. *Heat Treating and Forging*, November, 1939, pages 546–550, 5 illus., 7 tables.

Electrolytic Polishing of Stainless Steel. G. Kiefer. The rapid and cheap electrochemical polishing method for stainless steel which is described was developed by the Allegheny Ludlum Steel Corporation. Method is similar to electroplating except that flow of current is reversed. Metal is made the anode or positive pole of the system and space between anode and cathode and shape and area of cathode must be carefully determined for uniform luster. Phosphoric acid solutions produce a particularly high luster with a minimum of effort and expense. Corrosion resistant properties of the metal are not directly affected by the electrolytic treatment. Apparently the surface tension of the extremely smooth surface obtained is much lower than that of normally finished surfaces. Laboratory model of a continuous electrolytic polishing unit for handling stainless steel iron is illustrated. *Iron Age*, December 21, 1939, pages 30–32, 66, 3 illus.

Strain-Age-Hardening of Mild Steel. C. A. Edwards, H. N. Jones and B. Walters. Study of strain age hardening, with particular reference to the influence of small degrees of strain followed by aging at 250°C. Yield point in tension of normalized mild-steel specimens, up to a value of about 14 tons/sq.in. appears to be proportional to the number of ferrite crystals per linear millimeter. This is not the case when yield point is above 14 tons/sq.in. Amount of strain occurring at yield point is closely related to stress at which yield takes place. Abstract British Iron and Steel Institute paper. *Iron Age*, December 21, 1939, page 39.

Strain Annealing. F. J. Robbins. Data on various combinations of drafts and heat treatments and the resultant improvement in physical properties of the different S.A.E. steels, upon release of strain, particularly their machinability. Data presented in the previous issue indicate that no great flexibility of result can be expected by changes in draft alone. *Iron Age*, December 21, 1939, pages 37–39, 11 tables.

Non-Ferrous Alloys

Study of the Properties of Forged Magnesium Alloys. J. L. Haughton and A. E. L. Tate. Effect of work on mechanical properties of magnesium alloys, and effects of additions other than aluminum and silver to wrought magnesium alloys. Forging treatments of alloys containing varying amounts of aluminum, zinc and in some cases silver, and fatigue and compression tests are discussed. Effects of various additions and combinations of zinc, aluminum, cadmium and silver to magnesium alloys are described in detail.

Before low-temperature (200°C.) working can be carried out on magnesium alloys with best results, deformation given during the breaking-down treatment (330°–380°C.) must be sufficient to penetrate completely through the ingot. A reduction of 50 percent may not always be sufficient. A temperature of 200°C. was about the lowest at which pressing could be safely and practically carried out. Annealing between breaking down and low-temperature forging appears detrimental to the mechanical properties, but will enable some alloys to be forged at 200°C. which crack under press if not annealed. Fatigue limits determined on four selected alloys show that fatigue properties are somewhat improved by the low-temperature treatment, and ultimate compressive stress does not appear to be adversely affected. No alloy has been found which is greatly superior to the silver-aluminum magnesium alloys described in a previous investigation, but some containing no silver are comparable with them. From Journal (British) Institute of Metals, 1939, 65. *Heat Treating and Forging*, November, 1939, pages 552–558, 1 illus., 15 tables.

Spray Quenching of Light Metal Parts—Its Use in the Aircraft Industry. K. Scherzer. Method of solution-treating light alloys so as to avoid distortion. Spray quenching is claimed to give a product having the same properties as one quenched in water in the ordinary way, but it can be used for treating pre-shaped components due to the fact that warping is eliminated. A few typical constructional designs of equipment which have been tested in practice, operating details, and vertical and horizontal layouts are discussed. Paper prepared for the cancelled Aluminum Congress. *Metal Industry*, December 22, 1939, pages 523–525.

Testing of Metals

A Theory of Impact Testing. Long editorial on paper entitled "The Theory of Impact Testing: Influence of Temperature, Velocity of Deformation, and Form and Size of Specimen on Work of Deformation," by J. McAdam, Jr., and R. W. Clyne, and published in the "Proceedings of the American Society for Testing Materials," Vol. 38, Part II, page 112 (1938).

The authors deduce from published data that the greater the size of a machine part or structural member, the greater is its tendency to cold brittleness. The editor concludes that in this, as in one or two other respects, the theory formulated by the authors is not altogether convincing at present. *Engineering*, December 15, 1939, pages 667–668.

Torsional Damping Capacity. S. L. Barron, Cambridge Instrument Co., Ltd. Latest methods of recording measurements of torsional damping capacity are described which provide the metallurgist with an accurate indication of this property as well as a means of observing structural changes due to processing. Accessories for the pre-stressing of specimens and examination of records are also considered, and the method of calculation from record measurements is referred to. The Cambridge torsional damping machine is described in detail.

Modifications for recording at elevated temperatures, pre-stressing and torsional fatigue machine, stylus-on-celluloid method of recording, special microscope with micrometer scale and adjustable rotating table for measurement of disk records, optical method of recording developed as an alternative and specially designed to meet requirements of metals having low damping capacity and for tests at low stress are discussed.

The stylus-on-celluloid method of recording described is said to be an ideal method for recording stress and extensions in live members and for vibration and acceleration measurements in aircraft. *Aircraft Engineering*, December, 1939, pages 445–447, 461, 13 illus.

A Two-Load Method of Determining the Average True Stress-Strain Curve in Tension. C. W. MacGregor. Method developed at M.I.T. whereby complete average true stress-strain curve in tension may be determined for a material from the beginning of yielding to fracture under ordinary testing speeds by observation during the test of only two loads applied to a tapered specimen, namely maximum and fracture loads. Diameters at various positions along tapered specimens are measured before and after test, and stress and reduction-of-area values computed from these observations. *Jour. Applied Mechanics*, December, 1939, pages A156–A158, 4 illus.

Welding

New Process for Making Composite Metals. Purpose of the new process for the manufacture of composite metals by carbon arc welding, developed and patented by R. Kinkead, is to make available stainless-steel surfaces on ordinary steel, and applications are predicted in the field of tin plate, and galvanized sheets and plates. Surface of metal is alloyed in the steel-producing plant when in the form of an ingot or slab. Extensive work and tests in the production of low-carbon steels with an alloyed surface of chromium iron or 18 percent chromium and 8 percent nickel stainless steel has proved the perfection of the bond between the alloyed surface and base metal and that it is suitable for deep drawing. Short description. *Heat Treating and Forging*, November, 1939, pages 551, 563.

Spot Welding of Aluminium. New spot-welding machine intended for welding of aluminum alloys is described, the Ignitron control scheme of which provides means of effecting both current variation and sudden increase of pressure during the weld period. Principal characteristics of duralumin plate are reviewed to explain the reasons for the application of the Ignitron type of control. Formation of the weld is discussed and the macrostructure of welds made between 2–16 gage duralumin plates is described and illustrated. Results of an investigation made on the welding of duralumin plate on such a machine are dealt with. A method of surface preparation is recommended. Chart shows the relation between shear strength of spot welds in different thicknesses of four L3 duralumin plates to strength of different sizes of rivets when used to join two sheets of the same thickness. *Aeroplane*, December 8, 1939, pages 713–715, 10 illus., 1 table.

Brazing Aluminum Alloy Parts. G. O. Hoglund. Basic principles of batch brazing aluminum alloys by the furnace method. Brazing processes described should reduce joining costs as compared with standard gas and arc welding methods, will provide joints that require less finishing, and extend welding to parts thinner than previously possible. Alloys that can be brazed; strength of brazed joints; filler material and flux; removal of residual flux; furnace equipment; temperature and furnace time; and jigs and fixtures. *Iron Age*, January 11, 1940, pages 34–36, 59, 3 illus., 1 table.

Welding Magnesium Alloy Sheets. Gas welding of magnesium-alloy sheet, recommended sizes of rod for the various gages, use of fluxes, resistance

welding, and inspection methods are discussed. From the British journal, "Sheet Metal Industries," November, 1939. *Iron Age*, January 18, 1940, pages 48–49, 2 illus.

Paint

Scientific Testing of Finishes. References only to equipment used at the British Cellon works and other plants for testing finishes, including the Sheen Glossometer to test glossiness, Curgon Siccatometer to determine drying times, Sheen hardness rocker (illustrated) for testing hardness, another apparatus for determining point of maximum resistance to effects of bending, and apparatus for evaluating scratch resistance. *Aeroplane*, December 22, 1939, page 818, 1 illus.

Application of Zapon Lacquers to Metallic Surfaces. G. Zeidler and F. Wilborn. Zapon lacquers are those containing highly viscous nitro-cotton as important film-forming substance, and high degree of adherence to metallic surfaces is one of the characteristic properties required. Properties are subjected to a critical discussion. The authors believe that the characteristic technical properties of these lacquers should justify the addition of more valuable as well as more harmless solvents. *Paint & Varnish Production Manager*, December, 1939, pages 358–363, 373.

Film-Forming Plastics—Effect of Solvents, Diluents and Plasticizers. F. W. Reinhart and G. M. Kline. Properties of films formed from *airplane dopes* are affected by the four variables involved in their formulation, namely plastic, plasticizer, solvent and diluent. Data are presented on the solubility of various plastics in 21 common organic solvents and mixtures of solvents and diluents, and on their compatibility with 39 plasticizers. Degree of flexibility, clarity and shrinkage obtained with films prepared from plasticized and nonplasticized compositions is reported. Formulations of volatile components which yielded films having optimum flexibility and shrinkage, in so far as their use in airplane dopes is concerned, are listed for each material. These will serve as a basis for experimental dopes to be applied to fabric-covered test panels in order to determine their tautening and weathering properties. Investigation undertaken at the National Bureau of Standards and sponsored by the Bureau of Aeronautics. *Industrial and Engineering Chemistry, Ind. Ed.*, December, 1939, pages 1522–1529, 6 tables.

Plastics

The Nature of Adhesion. N. A. DeBruyne. Polar and nonpolar forces and rules of solution are explained, the adhesion rule is quoted, and the relation between joint strength and internal pressure of adherence is pointed out. The effect of heat is discussed.

It seems quite likely that cellulose can cross-link in a manner reminiscent of thermosetting synthetic resins of the urea-formaldehyde or phenol-formaldehyde type, and that when this has taken place, the cellulose can no longer be stuck with polar glues. Most high-quality plywood is made under conditions such that there is danger of a transformation taking place. When this happens, such plywood will pass all tests laid down in British B.S. Specification 4V3 for adhesion between its own veneers, but outer surface cannot be stuck to other components. The trouble only arises in thin plywood sheets. Method of test which might serve as a rapid means of detection is illustrated. Graph and table compare the internal pressures and strengths of joints made between optically polished metal surfaces with shellac adhesive (lead, tin, iron, copper, nickel and aluminum). *Flight, Aircraft Engr. Sup.*, December 28, 1939, pages 51–54, 6 illus., 2 tables.

A Note on the Elastic Properties of Vinyl Sheeting. S. Bateson, Duplate Safety Glass Co. of Canada. Specimens of vinyl sheeting examined recover completely upon unloading at temperatures below 50°C. During both extension and recovery, creep is pronounced, the elongation obeying an empirical law of the form $S = S_0 + a_1 t^{1/3} + a_2 t$. Elongation and birefringence are not strictly proportional but exhibit considerable lag. Elasticity, creep and birefringence all depend upon the temperature as well as upon the amount of plasticizer present. These properties are also influenced by viscosity of the polymer from which the acetal resin is derived. Samples selected for test were cut from standard du Pont sheeting 0.015 in. thick, the product consisting of a butyraldehyde replacement resin plasticized with "3GH." *Jour. Applied Physics*, December, 1939, pages 887–889, 4 illus., 2 tables, 1 equation.

Stress Properties of High-Strength Synthetic-Resin Plastics. A. Thum and H. R. Jacobi. German synthetic-resin plastics under tensile load, their strength, and the development of fractures are discussed, with many references to previous papers on plastics for aircraft. Minimum strength values (modulus of elasticity, and strength in compression, tension, bending and impact bending) are given for high-strength synthetic-resin plastics according to DIN 7701, including Type T-3, Hartgewebe Class F, Type Z-3 and Hartpaper Class II, and test results obtained with these plastics are described. *V.D.I.*, September 16, 1939, pages 1044–1048, 8 illus., 1 table.

Rubber

Koroseal, a Raw Material for the Rubber Industry. S. L. Brous. Outstanding characteristics and applications for which Koroseal is suitable. *India Rubber World*, December 1, 1939, pages 53–54, 4 illus.

Oxidation of Vulcanized Rubber—Effect of Temperature, State of Cure, and Thickness. A. R. Kemp, J. H. Ingmanson and G. S. Mueller. Previous investigation of the rate of oxidation of rubber over the temperature range of 60° to 80°C. has been extended to 90°, 100° and 110°C. Effect of time of vulcanization and specimen thickness on oxidation rate at 80°C. has also been determined. Studies were limited to the range of oxidation which accounts for substantial deterioration of physical properties. Physical deterioration has been correlated with quantity of oxygen absorbed. *Industrial and Engineering Chemistry, Ind. Ed.*, December, 1939, pages 1472–1478, 12 illus., 8 tables.

Bearings

Bearing-Testing Machine for Various Types of Load. E. A. Cornelius and E. H. Barten. Two types of bearing test machines have been introduced which operate with a load revolving with the journal bearing. In the first the rotating force does not vary during a single rotation, and in the second a variation in the rotating force does take place during a single rotation. In addition, there have been introduced test machines in which a sine-formed variable load can be superposed over the stationary load, and test machines which can reproduce impact by short-period rapidly variable loads. These types of machines are considered. Design, construction and method of operation of a test machine which permits combining the types of load mentioned are described. Tests and first test results are discussed. *V.D.I.*, November 18, 1939, pages 1219–1221, 6 illus., 1 table.

Fuels and Lubricants

Alkylation and Its Influence on the Unitization of Natural Gasoline. E. W. Gard, A. L. Blount and K. Korpi. Pilot-plant and small-scale experiments are described which were made with the following three olefinic fractions: mixed propylene-butylenes stock which was the reflux in the pressure-distillate stabilizer; a propylene-rich feed; and a butylenes-rich feed. Runs were made to determine the best operating temperature and experiments were made to determine how much excess isobutane was required to produce optimum yields under otherwise constant conditions. Tests indicated that, by choice of the olefinic feed stocks used in the alkylation process and by blending of the product with suitable straightrun fractions, aviation gasolines can be produced which will comply in every respect with the specifications of the Army and Navy departments for 87 (unleaded) and 92- and 100-octane-number aircraft fuels of various lead contents. Potentialities of the alkylation process are discussed, and estimated potential production of 100-knock-rating aviation gasoline by polymerization-hydrogenation and by the alkylation process is compared in a table. Concluded. *Oil & Gas Jour.*, December 21, 1939, pages 46–48, 5 illus., 3 tables.

Japan Is Ill Prepared to Weather Potential U.S. Embargo. H. Leopold. Japanese fuel research in recent months was mainly concerned with seismic prospecting, shale oil, oil synthesis and hydrogenation, and aviation fuels. Japan's efforts to open up independent sources have not borne fruit but dependence on American supplies has increased to more than 80 percent of her total imports. Japanese research on aviation fuel is reviewed in a general article also dealing with: prospecting subsidies voted by the Japanese parliament; estimate of crude-oil production 1931–1939; Sakhalin concessions issue; firm to produce aviation fuel; increased production of power alcohol; coal lubrication program as a flop; substitute fuels penetrating the market; estimate of imports; U.S. crude imports receding; American exports to Japan; government managed oil distribution; and oil-distribution problem. *Oil & Gas Jour.*, December 28, 1939, pages 160, 162, 164–165, 167, 168, 3 illus., 6 tables.

Tetraethyllead—Manufacture and Use. G. Edgar. Survey of the present status of the tetraethyllead industry, discussion of some of the less familiar problems connected with manufacture and utilization, and prediction of developments in the near future. Results of a General Motors Corporation research project to determine possibilities of increasing compression ratio under conditions in which the antiknock value of the fuel was no longer the limiting factor are quoted. *Industrial and Engineering Chemistry, Ind. Ed.*, December, 1939, pages 1439–1446, 5 illus.

Trends in Refining Practice. Among the many developments mentioned, the following are reviewed: research; production of fuels and other items by synthesis; effect of metallurgy; metals and alloys for refinery equipment; advance in high-octane fuels; thermal cracking; catalytic cracking; thermal polymerization; catalytic polymerization; catalytic hydrogenation; catalytic dehydrogenation; catalytic alkylation; thermal alkylation; catalytic isomerization; conbination units; heaters; fractionating towers; instrumentation; pumps; condensers and exchangers; valves; tankage; chemical treating; aviation gasoline; Diesel fuel; and lubricants. *Oil & Gas Jour.*, December 28, 1939, pages 260–308 (alternate pages), many illus.

Engine Design and Research

Aircraft Engines and Their Lubrication. A. Nutt. Development of aircraft engines is destined to continue at an accelerated rate during the next five years as results of research on details are applied. An increased number of types will appear as more care is taken to design special engine types for the various airplane types. A revival of liquid cooling will be seen, particularly for military work. Progress over the past fourteen years is reviewed as an indication of what has been taking place and what may take place in future.

Cooling, supercharging, dynamic damper, spark plugs, fuels, dynamic suspension, materials, compression-ignition versus Otto-cycle spark-ignition engines, fuel injection, coaxial propellers, liquid-cooled versus aircooled engines, engine types, sleeve-valve versus poppet-valve engines, and lubrication are discussed, and engines built in this country are compared with those built abroad. *S.A.E. Jour. (Trans.)*, December, 1939, pages 501–512, 33 illus.

The Diesel Engine with Side-Controlled Valves. H. Ernst. Conventional design of the Otto engine with side valves indicates how the present vehicle Diesel engine can be simplified in structure and be less expensive to build. Principal difficulty has been the combining of high compression ratio and sufficient flow cross-section in the structural solution. The described results, which were obtained with a test engine, demonstrate that this difficulty can be overcome, and indicate that, with the test engine, performance and operative values are obtainable which correspond to the commercial overhead-valve Diesel engines. Indicated performance and fuel consumption values permit expectations of useful values in the multicylinder engine of from 16 to 18 hp./liter maximum output and minimum fuel consumption values at full load of approximately 200 g./hp.-hr., as well as allowing the mechanical stresses which occur in the conventional Diesel. The design of the inexpensive side-valve Diesel, hitherto not applied, is therefore possible for a practical engine by the careful design of combustion-chamber dimensions. *A.T.Z.*, October 25, 1939, pages 539–541, 6 illus.

Engine Bearings—from Design to Maintenance. A. B. Willi. Faulty design or too much engineering compromise both in the bearings themselves or in associated parts of the engine are pointed out as major causes of bearing failures. Other causes of bearing failure; materials used in bearing construction; effect of temperature on the physical properties of white metals; the bearing back; oil flow to connecting-rod bearings; oil-feed-groove restrictions; oil clearance; elements of bearing manufacture which affect performance and life; length of tubes for centrifugally cast bearings; preparation of steel tube for babbitting; finishing the bearing back; more comprehensive specifications which are required; bearing failures caused by faulty installation and misuse and abuse in operation; and those caused by the use of inferior lubricants or good lubricants improperly prescribed and used; and rate of bearing deterioration. *S.A.E. Jour. (Trans.)*, December, 1939, pages 513–525, 36 illus., 1 table.

Exhaust Efflux Propulsion. F. W. Lanchester. First issue—Condition considered is that the efflux energy is derived as a tax on the engine power, each piston doing work during its return stroke, and experiencing back pressure in so doing. Question is whether and to what extent it will pay to use a portion of the power developed by the engine to promote exhaust efflux as an auxiliary means of propulsion, at expense of just that much power lost to the propeller shaft.

Efflux (or rocket) efficiency is computed for the same type of airplane previously discussed. In any actual application of exhaust efflux auxiliary propulsion, the idea of making use of power borrowed from the engine such as would diminish output available at the crankshaft may be dismissed unless the screw propeller efficiency is far lower than assumed. Only regime likely

to prove of value is that in which efflux propulsion is to be regarded as a means of utilizing energy derived by expansion carried beyond the point of release which would otherwise go to waste, the gain being shown to be substantial.

Second issue—The induction system is first considered as something apart by which the charge becomes or is made a part of the airplane, so that it may be subsequently treated on that basis by an application of rocket theory, and loss due to scooping up of the air has to be set off against gain at efflux. In the second line of approach adopted by the author, induction and exhaust, instead of being considered separately, are taken as a whole. The simple tube set with its axis parallel to the line of flight is first considered. Function of induction pressure as a means of effecting supercharge may be deemed justification for the loss due to direct flight resistance involved, and if this view is accepted, there is no longer any need to treat it as a setoff against gain. Concluded. *Flight*, December 7 and 14, 1939, pages 460 and 495–496, 2 illus., equations.

Gasoline Engine Combustion. H. Rabezzana, S. Kalmar and A. Candelise. Effect of various factors upon the reaction velocity as judged by behavior of flame velocity, and analysis of pressure-time relations to show effect of reaction velocity. Discussion covers: mixture ratio; spark advance; engine speed; throttle opening; temperature of unburned mixture; local heating; local turbulence; flame turbulence; and combustion time, power and detonation. Concluded. *Automotive Industries*, November 15, 1939, pages 632–639, 15 illus.

Liquid-Cooled Engines. A. G. Elliott. The liquid-cooled engine provides the motive power for the world's fastest fighters and bombers used by friend or foe alike. At this time the ability of the liquid-cooled engine to operate at super-normal boosts for emergency requirements should be remembered. Altitude development of the liquid-cooled engine; method of comparing engine performances on the basis of crankshaft horsepower (b.hp. plus power to drive the blower at the rated altitude) expressed in terms of hp./sq.in. piston area; foreign liquid-cooled engine practice favoring policy of using lower boosts and obtaining the same output by more engine capacity; propellers; engine starting and electric devices; development of engine materials; future developments; and progress of research. *Flight*, December 7, 1939, pages 464i–464l, 465, 6 illus.

Mathematical-Machine Determination of the Vibration of Accelerated Unbalanced Rotor. J. G. Baker. For an unbalanced rotor amplitudes of vibration are given for different rates of constant angular acceleration and deceleration. Setup used to obtain these results on the differential analyzer at M.I.T. is described briefly and illustrated. Selection of spring constant, damping and mass of suspended unit as a means of avoiding serious vibration in bringing a heavily unbalanced spring-mounted rotor up to speed is discussed in connection with the results. *Jour. Applied Mechanics*, December, 1939, pages A145–A150, 12 illus., 30 equations.

Operating Temperatures of Cylinder Barrel on Aircraft Engines. M. J. Becq. Operating temperatures resulting from improved and, in some cases, entirely new types of cowlings are given. Temperatures were taken on cylinder barrels and heads of engines used in the following airplanes of Air France: the twin-engined Potez 62 10-passenger airplane, twin-engined Bloch 220 16-passenger airplane, and the trimotor Dewoitine 338 22-passenger airplane. Successive modifications all resulted in increasing air pressures ahead of and behind the cylinders (0.45 lb./sq.in. in the case of the Bloch) and, in improving the distribution of air currents around the barrels, led to a diminution of entrance openings, the diminution of inside diameter of the leading edge of the N.A.C.A. type cowling, whereas diameter of the fixed screen behind the propeller or diameter of the propeller hub was increased to 23.5 and even 27.5 in. Efficiency of cowlings has a very favorable effect on the endurance of the equipment. Short abstract from Technique Moderne. *Automotive Industries*, December 1, 1939, page 572, 1 table.

Piston Ring Blow-By in High Speed Gasoline Engines. C. G. Williams and H. A. Young. A new theory of "ring flutter" is submitted, and tests are described in detail. Discussion includes: effects of side clearance and of radial pressure; effect of cylinder-bore distortion; effect of rate of oil flow; composition of blow-by gases; tests on a single-cylinder overhead-valve air-cooled engine; effect of running-in; effect of b.m.e.p.; effect of ring side clearance; effect of piston-ring width; effect of ring gap; effect of clearance behind the rings; effect of radial pressure; tests on bevelled rings; effect of wedge-shaped rings; effect of number of rings; and effect of oil viscosity; effect of spark advance.

Long report of the British Institution of Automobile Engineers. *Automotive Industries*, December 15, 1939, pages 614–622, 27 illus.

Recent Observations on the Ignition Process in Diesel Engines. K. Zinner. Process in the ignition of fuel injected into the Diesel engine demands increased attention since higher engine r.p.ms. are being used in which time available for ignition delay becomes shorter and shorter, and since it has become desirable to use fuel derived from coal which ignites with difficulty. Most important research results published in Germany and other countries are summarized and given a critical evaluation.

The ignition process in the Diesel engine consists of physical-treatment and chemical-conversion processes. For the ignition process of the fuel particles which first burn—the ignition delay—in the first place the chemical properties of the fuel and the condition of the combustion air affected by heating up and vaporization are decisive, while combustion of the remaining fuel is determined principally by the expiration of the mixture process between fuel and air. *V.D.I.*, September 30, 1939, pages 1073–1079, 8 illus., 1 table, 5 equations.

Study of Injection Requirements of High Speed Diesels Resulted in Equipment that Gives Good Performance and Is Satisfactory from the Manufacturing and Service Standpoints. L. E. Johnson. Injection research undertaken by the Caterpillar Tractor Company is described including: injection and ignition timing; injection system stability; injection beginning; and control of injection rates. Equipment used in research is also described. *Automotive Industries*, December 1, 1939, pages 580–587, 13 illus.

Tests on a Medium-Pressure Two-Cycle Injection Engine. R. Duell and F. Zahren. Test results obtained on a single-cylinder engine with crankcase scavenging pump, inlet slots and two outlet valves. Tests were made at a compression ratio up to 1:9 principally with gas oil, but also with light and heavy oils, and principally with self ignition but also with external ignition. Later tests were only made with gas oil, since the injection pump, in contrast to early tests on the four-stroke engine no longer worked without objectionable excessive wear. Tests were continued with 7.2 and 7.8 compression ratio. Speed was increased to 1600 r.p.m. while the mean piston speed was 11.2 meters/sec.

Self ignition of fuel in the test engine is obtained by means of: the two-stroke method; severe air turbulence; long stroke; small cooling area of the cylinder head; furnishing the scavenging air by crankcase pump; forcing up of the scavenging air at the lower portion of the uncooled cylinder liner; and the quantity of "rest gas" still present in the continuous scavenging flow. Tests still in progress extend mainly to the following points: increase of compression at simultaneous decrease of filling; making a further improvement of fuel consumption obtainable in this way; and tests with superchargers in progress for further increase of specific engine power. *A.T.Z.*, September 10, 1939, pages 482–484, 6 illus.

War—and the Development of the Aero Engine. A. H. R. Fedden. Greater necessity for continuing research during the war; advantages of the radial engine for wartime production in that its geometry is such that stressing is simple, design compact, material obtainable in large quantities, and layout such that assemblies can easily be isolated for production by subcontractors; possibilities of multibank radials with high outputs; a few of the problems to be overcome in creating engines up to 4000 b.hp.; supercharger developments being most needed; advantages of sleeve-valve engines in the future developments mentioned, and in servicing; and advantages of the interchangeable power unit developed by the Bristol company.

The author believes that to meet the exigencies of war a policy should be adopted of not attempting "to demand from the aircraft-engine power plant the highest specific output that might well, with reason, be expected from years of peace-time development, but that we should concentrate on absolute reliability for a limited prescribed life from more liberal volume engines." *Flight*, December 14, 1939, pages 490a–490d, 4 illus.

Rocket Efficiency. Criticisms of the method of evaluating the efficiency of rocket propulsion, which was used by F. W. Lanchester in his recent articles on "Exhaust Efflux Propulsion," are given by R. W. Corbett, C. L. Johnson, and O. Lawrence. The author's replies to each are included. *Flight*, December 28, 1939, pages 526–527, many equations.

Some New Investigations of Old Combustion-Engine Problems. G. Eichelberg. For the study of a new cycle of an internal-combustion engine, for example, of a highly supercharged Diesel engine, or for comparison of different processes, such as the influence of different heat losses, different combustion lines, and different scavenging effects, the entropy diagram is recommended as being of greatest help. Both the entropy diagram and research on fuel injection are discussed. Types of nozzles and pumps are described in detail, and the special difficulty with Diesel fuels which cause carbon deposits around the nozzle holes is considered. Continued. *Engineering*, December 22, 1939, pages 682–686, 18 illus., many equations.

Engine, Fuel and Lubricant Testing

The Admiralty Cathode Ray Oscillograph Engine Indicator. F. D. Smith, E. H. Lakey, and H. Morgan. Indicator developed at the British Admiralty Research Laboratory for use on compression-ignition engines of medium and high-speed types. Pressure-sensitive device is based on the magneto-phone principle. Pressure to be recorded deflects a steel diaphragm and changes an air gap in a magnetic circuit which is energized with alternating current of high frequency (20,000 periods/sec.) flowing in an encircling coil. Brief abstract of Institution paper as well as abstracts of two other papers to be presented, namely "Basic Principles in the Design of Cathode Ray Oscillograph Engine Indicators," by F. D. Smith and "Stress Measurement by Magnetostriction," by F. D. Smith and C. A. Luxford. *Inst. Mechanical Engrs., Jour.*, November, 1939, pages 185–186.

Deco Hand Pump Tests Injectors on the Engine. Hand pump for testing fuel injectors and other hydraulic devices consists of a pump unit having the same barrel, plunger, suction valve, and delivery valve as the Deco fuel-injection pump and is operated by means of a detachable handle. Short description and drawing. *Automotive Industries*, December 15, 1939, page 641, 2 illus.

A Laboratory Method for Evaluating the Influence of Lubricating Oils on Carbon Deposition. H. A. Everett and G. H. Kaller. The simplified and inexpensive laboratory test method presented was developed for predicting engine carbon-forming characteristics of lubricating oils and rating them with regard to this property. Method utilizes a battery of small single-cylinder engines operated under carefully controlled conditions. Long abstract, Pennsylvania State College Engineering Experiment Station Bulletin No. 48. *Engineering*, December 15, 1939, pages 676–678, 8 illus., 4 tables.

Piezoelectric Versus Mechanical Spring Pressure Gauge. R. A. Webster. Curves taken on two piezoelectric and one mechanical spring gage at Aberdeen Proving ground in collaboration with Eckert and Karcher are illustrated. These distinctly indicated on a simultaneous basis that the Curtis-Duncan spring gage actuated prior to the piezoelectric in the order of a millisecond. The difficulty with which leakage of the electric charge is kept to a negligible amount is cause for some concern for routine use of such a gage. One great advantage in the mechanical gage is the fact that it is a self-contained unit calibrated without the characteristics of a recording apparatus entering into the calibration, while the piezoelectric gage is only a charge producer with recording apparatus as a part of the gage. This fact therefore militates against accurate calibration in places where leads for conveying the charge have to be extended or passed near interfering inductive circuits. *Jour. Applied Physics*, December, 1939, pages 890–891, 1 illus.

Sees Inside Heads. Pike-O-Scope, an illuminated magnifier, has been devised by E. W. Pike and Company for examining the inside portion of a valve and valve seat, but can also be used for inspection of many other types of machinery. Set of achromatic triple lenses is lighted by a special lamp built into the bottom of a cylinder. Defects can readily be seen at a distance of 2 ft. from the eye. Brief reference only. *Automotive Industries*, December 1, 1939, page 596, 1 illus.

Test Laboratory Has Unique Control. Apparatus used for testing fuels and lubricants in the new automotive laboratory of the Point Breeze refinery of the Atlantic Refining Company is described. Regulation of equipment is effected from the seat of the car being tested instead of from the usual wall panel adjacent to the stand. Principal equipment consists of chassis and engine dynamometers, special fuel-testing sets, and friction- or bearing-testing machines. In the chassis dynamometer test room behavior of fuels and lubricants in passenger cars and trucks can be determined under widely varying conditions of temperature, wind velocity and load. *Automotive Industries*, December 1, 1939, pages 574–576, 4 illus.

Pratt & Whitney's New Experimental Test House. New building is designed solely for testing aircraft engines and not propellers. It is a reinforced concrete structure of two stories containing four identical test chambers. Short description. *U.S. Air Services*, January, 1940, page 37.

Engine Manufacture

An Adaptable Valve-Grinding Machine. Churchill Model BY valve-seat grinding machine; grinder on which there is a pneumatic chuck-operating mechanism; and a valve-head grinding machine adapted from the AY type. Descriptions. *Aircraft Engineering*, December, 1939, pages 459, 461, 4 illus.

Chrome Plating Cylinder Bores. Process developed by a Dutch engineer, H. Van Der Horst, is described, and effect of a coating of coarse-grained

chromium in reducing bore wear and piston-ring wear is described in quotations from the "Fourth Interim Report of the Automobile Research Committee on Cylinder Wear," by G. C. Williams. Process has come into extensive use in various European countries. *Automotive Industries*, December 1, 1939, pages 579 and 592, 1 illus.

Engines

Barrel-Type Engine Is Tested. K. S. Cullom, Civil Aeronautics Authority. Report on test of the Alfaro barrel-type engine. Engine is of the crankless type employing two cam plates actuated by double opposed pistons, and it operates on the two-stroke cycle with fuel injection and spark ignition. Four cylinders are parallel with the driveshaft and arranged symmetrically around it. In tests with 87-octane fuel, the engine developed 113 b.hp. at 2030 r.p.m. Weight dry 269 lb. Overall length 44$^{9}/_{16}$ in. Body diameter 15$^{1}/_{2}$ in. *Automotive Industries*, December 1, 1939, page 590, 1 illus.

British Aero Motors of 1939. Characteristics and output of 41 British aircraft engines. *Aeroplane*, December 15, 1939, pages 758–762, 33 illus.

Britain's Aero Engines. Details of British engines with references to the military and civil airplanes they power.

Leading characteristics are given in a table for 43 British aircraft engines. Photograph shows the installation of the Rolls-Royce Merlin in the Spitfire fighter, while larger photographs are given of the Merlin X, Kestrel XXX and Peregrine, Napier Dagger VIII, Bristol sleeve-valve radials, Armstrong-Whitworth Cheetah IX and X radials for trainers, Cirrus Major and Minor, and DeHavilland large and small Gipsy engines. *Flight*, December 7, 1939, pages 461–464, 464a–464h, 21 illus., 1 table.

Zlin Toma 4. Czechoslovakian aircooled 4-cylinder 4-stroke inline aircraft engine developing 110 hp. Bore 105 mm. Stroke 115 mm. Weight 98 kg. or 0.89 kg./hp. Fuel consumption 230 g./hp.-hr. Few details, dimensions and output. *Luftwissen*, November, 1939, page 295, 1 illus., 1 table.

German Engines. Principal characteristics and particular details of the engines used to power the military aircraft of the German Air Force. Table gives characteristics of 13 aircooled and eight liquid-cooled engines not only in service but also in development or in the experimental stages. For each engine a list is given of the military and civil aircraft which are equipped with it. *Rev. de l'Armée de l'Air*, September–October, 1939, pages 545–570, 27 illus., 1 table.

Lycoming Engine Production for the Light Airplane Market. Lycoming Models GO-145 C1 (single ignition), C2 (dual ignition), and C3 (dual ignition and accessory drives) 4-cylinder horizontally opposed aircooled engines for light aircraft, all developing 75 hp. at 3200 crankshaft r.p.m. With the use of a 27:17 reduction gear, propeller r.p.m. at this speed is 2015 and 1825 r.p.m. at cruising speed. Weights: C1 181 lb.; C2 192.5 lb.; and C3 193.5 lb. Bore 3.625 in. Stroke 3.50 in. Displacement 144.5 cu.in. Compression ratio 6.5:1. Long description of engines and of operations employed in their production. *Aero Digest*, January, 1940, pages 38–40, 15 illus.

Description of engine. *Aviation*, January, 1940, page 50, 2 illus.

Parts and Accessories

Equipment in the Aircraft Industry. Sintox, a special form of sintered oxide, has been developed by Lodge Plugs, Ltd., for insulating the spark plugs of high-speed aircraft engines. It is said to have a higher thermal conductivity than any other heat-resisting ceramic body and at least five times the impact strength (40 in.-lb.). Central electrode of the new spark plug is a platinum alloy wire 0.047 in. in diameter. Earth electrodes consist of three square platinum wires hydrogen brazed into a nickel ring. This design presents a minimum surface to the effect of erosion by hot gases at the same time affording large burning area. Tangential arrangements of earth electrodes make gap setting easy. Brief reference and drawing. *Aeroplane*, December 22, 1939, page 818, 2 illus.

Steam Power Plants

New Steam Power Installations for Vehicles. Since in the case of high performances, steam power plants, in view of their weight and efficiency, may enter into competition with the internal-combustion engine, the use of the steam drive for aircraft has been recommended by foremost engineers. Inasmuch as the engine installations of new large-size aircraft used for covering long distances today have a total power of from 4000 to 6000 hp. and larger outputs will be required for transoceanic aircraft, such a line of thought should not be disregarded. Various new types are described including: further development of the rotary-boiler turbine by F. Huettner (discussed in V.D.I., April 8, 1939) and a multistage, rotary boiler turbine of 100 kw.; the steam engine built by the French engineer Bechard the disk boiler of which is turned by the reaction of the emanating steam (thereby producing the useful work) and consisting of three to six disks; and a test machine ordered built by the French War Ministry the six-section boiler of which has a content of 6 liters of water (described also in "Engineer," Vol. 165, No. 4300); and the steam power plant built by the Besler Corporation of America with completely automatic boiler and burner control. *A.T.Z.*, September 10, 1939, pages 485–486, 6 illus.

Aircraft Radio

Aero Radio Digest. Finch radiofacsimile duplex (combined transmitting and receiving) unit. Bell Telephone 1940 research plans. New Radio CAA type certificates granted. Companies providing frequency measurement service to aircraft transmitter owners. Western Electric new two-way radio communication system, designed for ATR type mounting and intended primarily for airline use. RCA light-weight radio Model AVR-20 receiver, intended for private aircraft and airline use. Report No. 8 on circuit design for low-frequency radio ranges, issued by Radio Development Section of CAA's Technical Development Division. Short descriptions of radio equipment and brief abstract of report. *Aero Digest*, January, 1940, pages 163–164, 6 illus.

Service Apparatus for Aircraft Radio. H. W. Roberts. Specialized service equipment needed for aircraft radio work (some of which is not available and must be made by the serviceman himself), and the serviceman's qualifications are described in detail. Outstanding new instrument for servicing UHF aircraft radio in general is the Weston Electrical Instrument Corporation's Model 787 Type 2 UHF aircraft oscillator designed in cooperation with one of the leading airlines. Oscillator operates in the range 22–150 mcs. with all frequencies fundamental. Special tools for servicing the associated and related electrical equipment are also discussed. *Aero Digest*, January, 1940, pages 42, 45, 6 illus.

The National Physical Laboratory. Researches undertaken in the Radio Department are described, including: radio sounding balloons; cathode-ray direction finder; stability of radio circuits; and nature and sources of atmospherics. *Engineering*, December 8, 1939, pages 644–646, 3 illus.

Book Review

Aircraft Radio and Electrical Equipment, by H. K. Morgan; Pitman Publishing Corporation, New York, 1939; 369 pages, $4.50.

This book is of particular value to the airplane designer who is not familiar with the problems and limitations of radio installation and operation on aircraft.

By its excellent presentation of the airplane designer's problems it suggests to the radio designers how they can best coordinate their efforts with his and arrive at the best compromise consistent with weight, disposition, and the aerodynamic and practical considerations of antenna installations. Until recently the required provision for radio has been undertaken with reluctance by the airplane manufacturer and was usually left until the plane was built. The book under discussion should help reconcile the divergent problems of the radio and airplane designer.

The inclusion of many detailed radio circuits of current equipment renders much of the book impermanent as a general reference work. Radio art is still in too great a state of flux for stability of design. Save for typical general descriptions of basic types of design it is thought that most of these might have been omitted particularly in view of the fact that the radio manufacturer furnishes such data with each equipment. More emphasis could advantageously have been placed on those features of mechanical design which contribute reliability under the adverse conditions of aircraft installation.

As a current reference work for pilots and maintenance men the book is especially useful.

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